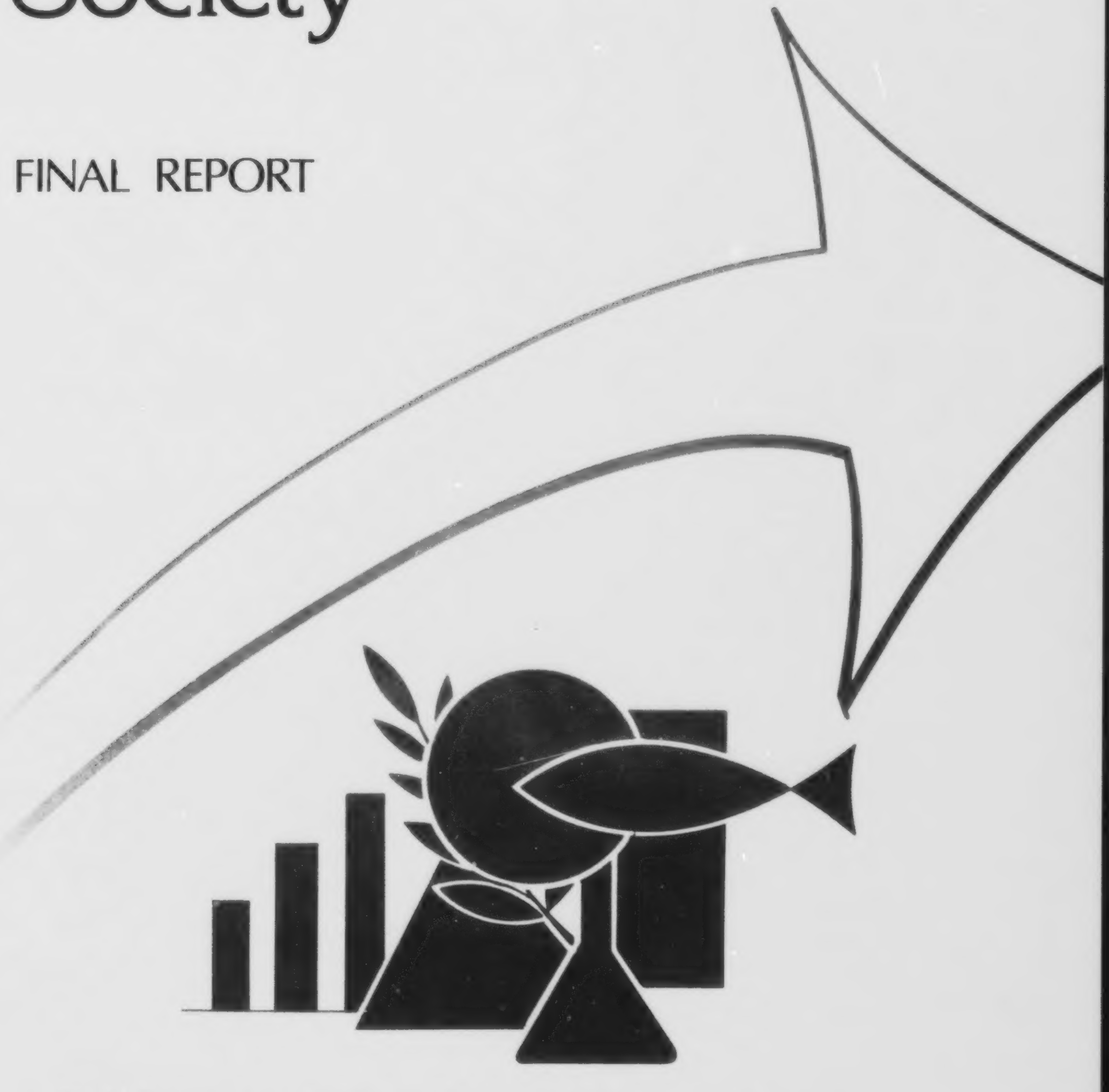
Towards an Achieving Society

FINAL REPORT



Task Force on Mathematics and Science Education

May, 1989

FINAL REPORT

TOWARDS AN ACHIEVING SOCIETY

TASK FORCE ON MATHEMATICS AND SCIENCE EDUCATION

May, 1989

90-00533/

May 23, 1989

The Honourable Clyde K. Wells, Premier
Province of Newfoundland and Labrador
Confederation Building
St. John's, Newfoundland

Dear Sir:

I have the honour of submitting herewith the Final Report of the Task Force on Mathematics and Science Education, along with a Summary Report and supporting documentation.

The Task Force was appointed following expressions of concern that low levels of achievement and participation in mathematics and science programs are having detrimental effects on educational and career opportunities for large numbers of young people in the province.

In preparing the report, I have attempted to be forthright about the problems which confront the educational system. As its title indicates, the report calls for a renewed emphasis on attaining higher levels of educational achievement for much larger numbers of our young people. The fundamental transformations now taking place in society demand no less. This renewal can occur only if all parts of the education system, and indeed all citizens of the province, can achieve a unity of purpose, and work diligently towards achieving that purpose.

Fortunately, the ability to do this is within our own control. Throughout the work of the Task Force, I have been impressed by the high degree of sincerity and good will which exists within the system, and by the importance attached to education by all sectors of society. At the same time, it is clear that political leadership is required to ensure that energies and resources are channelled in the most productive directions.

Yours sincerely

Robert K. Crocker

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PREFACE

The Task Force on Mathematics/Science Education was appointed by the Government of Newfoundland and Labrador in early 1988, following expressions of public concern over levels of achievement and participation in mathematics and science programs throughout the educational system. The main focus of this concern was on evidence which pointed to a substantial decline in success rates in first year mathematics courses in the provincial post-secondary institutions.

The Task Force was given a broad mandate to investigate the problems of mathematics and science education. The work was carried out through a number of research studies, some completed by Task Force Staff, and others contracted to external experts. The results of these studies have been summarized in a series of 15 background reports. (A list of report titles is given in Appendix A.) The main discussion of issues is contained in this final report. In addition, a separate summary report has been prepared for the benefit of those interested in the main findings and recommendations, but who wish to avoid the detailed data and arguments.

A call for submissions yielded about 100 briefs and letters from educational agencies, professional groups, interest groups, and individual citizens. (A list of submissions appears in Appendix B.) The submissions were supplemented by interviews with several hundred groups and individuals, and by surveys directed at many others. The Task Force also had access to all important data files on achievement and participation in mathematics and science, including public examination records, student records from the various post-secondary institutions, and reports on several other testing programs conducted over the past few years. Documents reviewed included all curriculum guides, textbooks, and other materials provided in support of the provincial curriculum, comparable documents from other provinces, and reports of similar Task Forces and Commissions in other jurisdictions. Finally, reference was made where required to basic research on mathematics and science education, teaching, and broader issues such as grouping and time use.

Officially, the Task Force was a one-person appointment. I must therefore assume responsibility for the contents of the final report, and for the recommendations. Nevertheless, the study could not have been completed without the assistance of a highly dedicated and hard working staff. My decision to keep this staff small for the sake of efficiency added to the burden on those who joined the study. I am most grateful to Marian Fushell, Glenn Luther, Dolores Mills, and Cheryl Perkins for their contributions to the data gathering, management, and analysis. Thanks are also due to Charlotte Strong for her outstanding work in a broad range of management, writing, and editorial assignments. Helen Banfield, in her capacity as Research Director, performed her usual marvellous job of coordinating a multitude of research, data management, analysis and writing tasks. Finally, I am indebted to Charles Lester, our Executive Secretary, whose expertise in the workings of government smoothed the administrative path, and allowed others to concentrate on the substantive tasks at hand.

Aside from staff, a large number of other individuals and groups also contributed to the study. Thanks are extended to Warren Cole, Lloyd Gill, and Jacinta Sheppard for their work on the high school curriculum analysis; to Gary Hancock, Janice Kelland, John Pickavance, Bernard Rice, Donald Rideout, and Cyril Snook for the comparative study of first year university courses; and to Warren Cole, Lloyd Gill, Andre Grace, Leslie McLean, and Frank Murphy for the analysis of public examinations. I am indebted to a large number of individuals in the school system and the post-secondary institutions for assisting in the administration of the surveys and in the compilation of data. Finally, I am most grateful for the time and effort of all those who prepared submissions, provided data, subjected themselves to interviews, and responded to our surveys. The citizens of the province, represented by these individuals and groups, are the ultimate clients of the study, and the ultimate judges of its usefulness.

Robert K. Crocker

May 16, 1989

PART I

THE PROBLEM AND THE CONTEXT

CHAPTER 1

INTRODUCTION AND OVERVIEW

Why Such a Study?

In the Speech from the Throne presented at the opening of the House of Assembly on March 10, 1988, the Government of Newfoundland and Labrador announced its intention to establish a "Task Force to study the problems of mathematics and science achievement among students entering post-secondary institutions in the Province. The appointment of a one-person Task Force, and the announcement of its terms of reference was the subject of a statement in the House by the Minister of Education on May 24, 1988. The Task Force was given a broad mandate to investigate the extent of the problems in mathematics and science, to determine the causes of such problems, and to recommend solutions.

The manner in which the Task Force was brought into existence suggests that the problem to be investigated was not an ordinary one which could be addressed from within the system. Most public inquiries of this sort are established to examine broadly-based problems, with important public policy implications. What, then, served to draw the attention of government to such a specific aspect of education? The answer seems to spring from both immediate and long term concerns.

The immediate concern is illustrated by the trend illustrated in Figure 1.1 A substantial decline in success rates in first year mathematics at Memorial University is clearly indicated by this graph. Similar, though less extreme, declines have also occurred at other post-

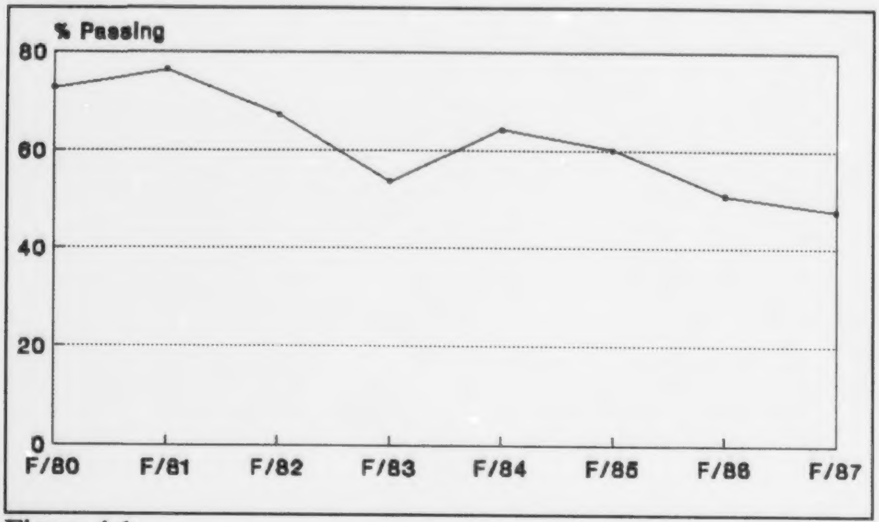

Figure 1.1
Pass Rates in Fall-Semester Mathematics, Memorial University, 1980-1987

secondary institutions. The immediate problem, therefore, is to determine why this decline has occurred. It is easy to understand why the public would view such figures with some alarm, and why government might be prompted to act. Failures at this level are perceived to represent substantial losses, both to the individuals concerned and to society as a whole. Because mathematical competence is prerequisite to so many other areas of study, such high levels of failure in mathematics, more than in any other subject, result in educational and career options being closed for very large numbers of young people.

The longer term concern of government is perhaps reflected more in its decision to include science as part of the inquiry. The ministerial statement referred to a problem of low participation rates in science programs, particularly the physical sciences. The statement also acknowledged a close link between science and technology and the economic well-being of the province. The inference is clearly that government viewed low enrolments and poor performance in science and technology areas, and particularly in the mathematics courses which provide a foundation for these areas, as detrimental to the goals of economic development. Indeed, it has become almost an article of faith in our society that a high level of competence in science and technology is a key element in economic growth, and crucial to the ability of the province, and indeed the nation, to compete economically.

Some sense of the problem of participation in post-secondary science can be conveyed by a few simple facts. Over the past several years, Memorial University has awarded an average of only 10 undergraduate degrees in chemistry and 13 in physics per year. Mathematics has fared only slightly better, with an average of 33 graduates per year. The problem at the other post-secondary institutions is slightly different, but no less troubling. Fewer than half the students who enter the various technology programs at these institutes actually survive to graduation. Much of the attrition occurs in the first year, and there is considerable concern within the institutions that poor performance in mathematics and science is one of the main reasons for the loss.

The broader question is that of the importance of mathematics and science education in our society, and the requirement for highly qualified people to meet the demand in science and technical occupations. Put in these terms, of course, the problem may be seen as a national as much as a provincial one. Indeed, there has been substantial concern about the same issue on a national level. This concern is shown in a study completed a few years ago by the Science Council of Canada.[1] Some federal initiatives have already been taken, most notably the establishment of a program of undergraduate science scholarships. However, with education as a provincial responsibility, it is fair to say that the only way in which substantial change can be achieved in the schools and colleges is if the problem is tackled at the provincial level. This study is thus particularly timely, in light of national concerns and initiatives in science and technology education.

A further reason why such a study is timely is that it has now been five years since the first graduates have emerged from the revised high school program which accompanied the introduction of grade 12 in this province. The major thrust of the revised high school program was on giving students access to a much broader range of courses than was previously available. This thrust was controversial from the beginning, since its consequence was that regular academic subjects, particularly mathematics and science, were not upgraded under the new program, despite the availability of an extra year of schooling. While a wide variety of new courses have appeared in the high schools in recent years, there has been essentially no change in the academic mathematics and science programs.

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[1] Science Council of Canada, **Science for Every Student: Educating Canadians for Tomorrow's World.** Ottawa: Supply and Services Canada, 1984.

More broadly, it may be argued that the major focus of educational change over the past couple of decades has been in the direction of improving the capacity of the system to retain students through to high school graduation and beyond. This emphasis is reflected in the final report of the last major review of education in the province, completed in 1980.[2] The title of that report, **Improving School Retention and Post-Secondary Participation,** pointed to a view which has characterized developments in education in this province throughout the 1980s. In terms of specific action, the emphasis is manifested in the growth of special education services, the focus on dropouts, the development of the community colleges, and other activities designed to improve access and opportunity in education.

This raises the question of whether educational performance has been sacrificed to participation, and if so, whether such a sacrifice is necessary. That is, as increased numbers of students find their way into higher levels of education, is it inevitable that average levels of achievement will be diminished? Whether or not such a trade-off is necessary, it is not surprising that efforts to improve participation would result in some neglect of standards of performance. Those responsible for educational policy and programs can do only so much. Science and mathematics programs, in particular, have remained essentially static during a decade of strong growth in participation in both secondary and post-secondary education.

This has occurred during a period of unprecedented technological advance. To understand the scope of this change, one has only to mention the revolution that has occurred in all sectors of society since the introduction of the microcomputer less than ten years ago. There is scarcely an area of home or occupational life that has not been touched by the microcomputer or by other applications of microprocessor technology. The educational implications of such change are only beginning to be recognized.

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[2] Task Force on Education, **Improving School Retention and Post-Secondary Participation.** St. John's, Government of Newfoundland and Labrador, 1980.

Scope of the Investigation

The announcement of the study called for a comprehensive review of the extent of the problems in mathematics and science and their possible causes, along with recommendations for their solution. More specifically, the scope of the investigation was determined by the following Terms of Reference:

1. Determine the extent of the problems in mathematics and science achievement at both the secondary and post-secondary levels.

2. Determine the causes of the problems which have been identified in mathematics and science.

3. Recommend specific actions to improve participation and achievement rates in mathematics and science at both the elementary-secondary and post-secondary levels.

In attempting to fulfil its mandate, the Task Force undertook a variety of tasks, in the following main areas:

1. **Programs**

    - Review of goals of mathematics and science teaching.

    - Comparative analysis of high school mathematics and science curriculum in Newfoundland and other provinces.

    - Comparative analysis of first year university courses in mathematics and science in a selection of Canadian universities.

- Detailed review of curriculum guides, textbooks, and other relevant documents used in schools and post-secondary institutions in this province.
- Review of program structures, with particular reference to the reorganized high school program, the proposals for reorganization of the junior high school program, and the first-year programs in post-secondary institutions.

2. Achievement Levels

- Comparisons of achievement levels in this province with those in other provinces and other countries.
- Comparisons of achievement levels within the province over time.
- Analysis of public examinations and other major components of the evaluation system.
- Analysis of evaluation practices at the post-secondary level.

3. Participation Rates

- Comparative and historical analysis of overall enrolments at the secondary and post-secondary levels.
- Comparative and historical analysis of enrolments in relevant courses at the secondary level.
- Analysis of the production of graduates in mathematics and science disciplines and in relevant professional and technical fields.

4. Teaching Practices

- Analysis of teacher qualifications and related variables.
- Analysis of basic components of the instructional system (class size, facilities, time, etc.).
- Analysis of instructional practices.

5. Attitudes and Perceptions

- Survey of attitudes of high school and post-secondary students.
- Survey of teacher and instructor attitudes.
- Public opinion poll with emphasis on goals and programs.
- Interviews with major stakeholders.
- Solicitation of submissions from individuals and organizations.

These tasks were carried out through a number of research studies, some completed by Task Force staff, and others contracted to external experts. The results of these studies have been summarized in a series of background reports. (A list of report titles appears in Appendix A.) In addition, about 100 briefs were received, and several hundred persons and groups were interviewed. The Task Force was given access to all important data files on achievement in mathematics and science, including the public examinations records, student records from the various post-secondary institutions, and reports on several other testing programs conducted in recent years. In fact, the bank of achievement data was considered sufficiently complete that it was necessary for the Task Force itself to conduct only two small scale testing programs, in grade 7 and 8 science. These were designed to provide some comparative data, particularly on a test designed specifically for use in this province, at the end of the elementary science program.

Limitations

As in most policy studies, it was necessary to live with several important limitations, stemming largely from the absence of basic research on certain issues, and from the inherent inability to conduct such research within the time and resource constraints of a policy study. The first major limitation is in the incomplete knowledge which we possess of how students learn mathematical and scientific concepts, and why such concepts present such serious difficulties for so many. While there is substantial basic research in this area, it is not yet possible to give clear prescriptions for overcoming specific difficulties in mathematics and science learning.

A second limitation lies in the inability to learn enough about what is actually happening in the classrooms of the province. It is one thing to conduct surveys on teaching techniques, or to seek opinion in this area, but quite another to engage in the sort of large scale observational work that would be necessary to get a first-hand picture of classroom events. Fortunately, there is a reasonably good body of literature on classroom processes, including some work done in elementary and secondary schools in this province. To the extent possible, such work will be used both to describe what is happening and to identify areas in which change should occur. At the post-secondary level, however, there is little observationally based knowledge.

One or two further limitations were deliberately imposed in order to keep the study to a manageable scale and to reduce the range of expertise required. The study has not looked in any detail at post-secondary programs beyond the first year. Thus, no judgements have been made on the quality of overall university degree programs, graduate studies, or research. Any comments related to these areas have to do with participation rates and with implications for teaching at the lower levels. The other area not examined in detail is that of science and mathematics courses in trades and other community college programs, other than technology programs. The latter institutions are in such a state of flux at this time that it is difficult to make any sort of judgement on specific courses. Nevertheless, there are a number of points in the study which have major implications for the community colleges, and which it is hoped will be considered as the community colleges evolve over the next few years.

The Immediate Problem: Failure in Mathematics

Although the mandate of the study required a broad examination of all aspects of mathematics and science education, it was necessary to ensure that the immediate problem of failure in mathematics was addressed directly. While an overall plan for improvement of mathematics and science teaching would be expected implicitly to ameliorate this problem, it became clear early in the study that specific short term changes would be required in senior high school and first-year post-secondary mathematics. Much of the emphasis in the interviews and submissions was on this problem. It was necessary at the beginning to identify the range of possible contributing factors to high failure rates.

This section gives a brief overview of the main factors. Some of these were identified in preliminary discussions with various interest groups. Others emerged from a systematic attempt by the study staff to identify all plausible causes, and not to rely solely on initial opinions. It was particularly important for the study not to be unduly influenced from the beginning by any particular viewpoint. All such viewpoints were treated merely as preliminary hypotheses to be investigated. The essence of the investigation, as in all such studies, was to determine which hypotheses should be ruled out and which should be retained. It was expected from the beginning that the problem would not have a single cause, and that some of the causal factors would be beyond the control of the educational system. At the same time, there was little point in starting with the assumption that the problem was so complex that no solution would be possible.

From the point of view of the post-secondary institutions, the most direct contributing factor was seen as the lack of basic algebraic skills on the part of students. Example after example was cited to illustrate inability to perform operations such as factoring, collecting terms, reducing to lowest terms, cancelling, adding to both sides of an equation, and the like. These, in turn, result in inability to solve equations or simplify expressions. Sometimes the examples involved improper application of basic arithmetic operations, inability to judge the plausibility of a computed result, unfamiliarity with standard symbols, lack of knowledge of standard units of measurement, and similar basic skills. All of these capabilities are simply taken for granted in post-secondary courses (and indeed in the more advanced high school courses). A student who cannot perform such operations is obviously not going to be able to succeed in any area of higher mathematics, no matter how well the new material might be taught.

Acknowledging this problem merely leads to the next question, namely, why are such skills lacking? Many possible hypotheses were offered in answer to this question. These skills may not be included in the high school curriculum, they may be taught poorly, they may be forgotten by students, they may not have been adequately practised, students may be entering post-secondary courses who do not have the basic underlying ability to cope with symbolic operations, and so on. At a deeper level, one might ask whether high schools should teach such things or whether the post-secondary institutions should look after their own prerequisites rather than assuming that students possess these on entry.

A second major factor emerging from the interviews and submissions concerns the content and pacing of the post-secondary courses. Students, in particular, frequently complained about a barrage of new topics being presented in rapid succession in lecture format, with no time for review, practice, or student questions. Many noted the sharp contrast between this approach and that taken in high school, where the pace is distinctly more leisurely, and where much of the time is taken by seatwork exercises, accompanied by teacher assistance to individual students. While there was general agreement about the difference in pacing, conflicting views were expressed as to whether this means that post-secondary courses are too intensive or that high school courses are too relaxed. This conflict must therefore be addressed in the analysis.

Evaluation practices in both secondary and post-secondary programs were also the subject of much early discussion. It was clear from the outset that there is a major contrast between secondary and post-secondary systems in their methods of evaluation, and particularly on the degree of reliance on final examinations. The view was frequently expressed that post-secondary final examinations were too long and based on greater depth of treatment of topics than occurred as the course was taught. At the secondary level, the argument took the reverse view, namely that the secondary school evaluation system is set up in such a way as to give an inflated measure of student proficiency. More generally, the view was expressed that substantial grade inflation has occurred in recent years, as more and more lower ability students find their way to the senior secondary and post-secondary levels.

Closely related to the issue of evaluation is that of admissions policies in the post-secondary institutions. The opinion was often expressed that the university, in particular, has been too liberal in its admissions policies, and that the policy of offering a place to all who meet the minimum entrance requirements has led to deterioration of teaching conditions, as enrolments have increased. Coupled with this was the view that grade inflation and broader course selections at the secondary level have resulted in an increasingly larger pool of marginal students being admitted. The situation has been somewhat different in other post-secondary institutions, which have always had quotas on admissions. At the same time, changes in admissions policies and, in some cases, difficulties in recruiting sufficient students to fill programs, have lead to the same sort of problems.

At a still more general level, a common view expressed was that the revised high school program has contributed to a deterioration in performance expectations. This argument is based on the idea that increased breadth in program selection, along with liberalized graduation requirements, have allowed students to complete high school with less effort. More specifically, with reference to mathematics, a loss in time available for mathematics was frequently noted, and is readily documented. Opinions differed, however, on the seriousness of this problem, and on whether or not there had been some overemphasis on mathematics in the earlier program.

A number of general arguments about student work habits were invoked in the context of mathematics performance. It was often argued that students today do not work as hard as their predecessors did, that engaging in part-time paid work distracts from studies, that residence life or various other living arrangements make it difficult for students to concentrate, that students are not sufficiently goal-oriented, or that students have become dependent and fail to take responsibility for their own success or failure. Some of these points are amenable to analysis, while others seem to be part of the folklore of education, being invoked when other explanations for poor performance fail.

One of the most troublesome groups of factors has to do with student ability and with home and community circumstances. It is well known that such factors are strong contributors to student achievement in general. Since these are essentially outside the control of the school system, there is a tendency for some educators to assume that nothing can be done to improve performance on the part of students who come to school with various deficiencies in their backgrounds. In the extreme, a self-fulfilling prophecy may be created, in which students are not considered at risk if their performance is poor, but only if their performance departs from expectations. Although there is considerable controversy in the literature over the extent to which expectations influence achievement, there was ample evidence in our submissions and interviews that some teachers and officials within the system act in ways which would allow self-fulfilling prophecies to occur.

A number of these factors are, of course, applicable to performance in other subjects as well as in mathematics. In fact, this gives us one of the most powerful tools for analysis of the problem. For example, to the extent that recent declines in achievement are unique to mathematics, certain causes can be ruled out, as these would be expected to yield comparable declines in other subject areas. A comparison of trends in mathematics with those in other subjects allows us to shed some light on this point. More broadly, it is not possible to investigate problems in mathematics without addressing some of the more general problems in the system. Such problems were examined as far as possible, within the mandate of the study.

Underlying Policy Issues

We take for granted that in establishing the Task Force, government was acting out of a sense that the observed problem is one of substantial public concern. Underlying this de facto argument for an investigation, however, are a number of important questions which were either not raised at all, or were simply alluded to in the original announcement.

The first question is that of whether there has been a real decline in performance or whether this is a perception arising from increasing expectations. For example, some have argued that the first year of post-secondary education has replaced the last years of high school as the time at which serious students in science and mathematics are identified and separated from their less able and interested colleagues. A more general, but related, point is that the source of the problem lies in the liberal admissions policies of the university and other institutions - policies which allow unsuitable students to enter the system at this level. Reversing this argument is the point that liberal admissions policies at least give everyone a chance to succeed. If students do not do so at the first year level, then they have had a chance, and the education system owes them nothing more. Such arguments would lead to an acceptance of high failure rates as inevitable, and therefore not problematic.

A second line of argument has to do with the assumption that there is a high demand in the workplace for persons with mathematics and science related backgrounds. Indeed, this argument was one of the few explicit ones presented by government as a reason for the study. Obviously, it is important to assess the validity of this assumption, since, if it is not valid, the problem could be solved simply by becoming much more selective in admissions to the relevant courses (not necessarily to the institutions themselves). While it was not possible to do a complete job market analysis as part of the study, it was possible to draw on various sources of evidence related to this point.

A broader argument relates to the social consequences of low success rates. This argument may be divided into two parts. The first is one of scientific literacy. While there is no denying the value to a society of having its citizens enlightened in matters of science and technology and its social consequences, it is much less clear that low success rates at the post-secondary level are in any way related to this objective. In fact, one might go as far as to argue that scientific literacy is not a matter for post-secondary education, or that the requirements for high success rates in post-secondary courses may be quite different from the requirements for scientific literacy. If the latter is true, then low success rates may, in fact, be a consequence of an approach to mathematics and science at earlier school levels which is based on developing literacy rather than technical competence. This point obviously needs to be explored.

A second social issue is that of the consequences of low success, in itself and in terms of denial of further opportunities and of lowered self-esteem. Some would argue that low success is demoralizing and results in students being discouraged from further educational pursuits. More directly, it is clear that failure in first-year mathematics and science closes many doors to further opportunity simply because of the failure to meet prerequisites. What is important here is to ask whether many of the prerequisite requirements which have become established are, in fact, needed. Again, we have heard the argument that mathematics prerequisites, in particular, are simply used as convenient screening devices to facilitate selection into limited enrolment or quota based programs. If this is so, then the denial of opportunity inherent in prerequisites is not a legitimate one.

The opposite side of this argument is the possibility that in attempting to ensure high rates of success in the school system, we have created an illusion which falsely equates high marks and pass rates with high levels of achievement. One of the major contributing factors leading up to this study was the shock experienced by so many students who scored well on high school examinations but who suddenly faced failure in the earliest stages of their post-seconday careers. Many individual cases can be cited to illustrate this point. Stories abound in the system of students departing their local communities in September with high hopes, based on their high school performance, only to appear again by Christmas having failed several university courses, especially the particularly notorious mathematics course.

It is easy to obtain an impression that the high school program is highly successful simply from the annual announcement that almost all (typically about 85 percent) of those writing public examinations in June have achieved passing grades. Clearly the large gap in success rates between high schools and post-secondary institutions is a signal that something is wrong. Whatever our views about the individual and social importance of success, it must be recognized that success based on an illusion will ultimately turn to failure. One of the main concerns of this study was to determine whether such an illusion has been created.

One of the arguments most widely heard during the course of this study was that high schools are no longer preparing students adequately for entry to post-secondary education. Behind this argument, of course, is the unstated assumption that secondary schools **should** be fulfilling this function. Again, judging from interviews and submissions, there are many who would question this as a primary role for the high schools. Obviously this issue must be resolved, particularly as it relates directly to the underlying structure of the revised high school program. Since this cannot be resolved through direct evidence, it is necessary to ask whether there is common ground between a post-secondary preparatory role and other roles for secondary education, or among the advocates of various positions on this issue. Any specific recommendations which influence high school programs must be based on a firm position on this issue.

In sum, therefore, the policy issues underlying the study are those of the importance of scientific literacy and scientific and technical competence, the economic and social consequences of low participation and success rates, accessibility to post secondary education, and the role of the high schools in preparing students for higher levels of education. Little progress can be made in resolving some of the more detailed problems of program structure, curriculum, instruction, or evaluation, without taking a specific position on these issues. Developing such a position is therefore the first major task of the study. This is where the various attempts to assess public and professional opinion, and to review relevant policy documents and other literature, are of value in the investigation.

Overview of the Report

This report is divided into three major parts. **Part I** addresses the underlying policy questions, and presents an overall framework within which the more specific analysis of programs has been conducted. This part is concerned with what the system **should** be seeking to accomplish. An attempt is made to determine where consensus exists on basic issues and where there is likely to be substantial controversy. As far as possible, an effort will be made to assess the merits of the arguments on all sides of a policy issue. Nevertheless, whether or not a particular point is controversial, a specific position is taken in this report, in order to ensure that a coherent approach is taken throughout the report. This part contains several general recommendations on policy. These are translated into recommendations for specific program action in the final part of the report.

Part II presents a summary of the basic data gathered during the study. Particular emphasis is placed on the analysis of participation levels and performance levels of our students. A summary is also given of the perceptions, opinions, and attitudes expressed in submissions and through the various surveys conducted. Much more detail on these and other matters appears in the background reports. (A complete list of background reports is given in Appendix A.) Only those details thought to be most significant for the subsequent discussion actually appear in this report.

Part III is devoted to an analysis of a number of specific components of mathematics and science programs. A specific analysis is given of the immediate problem of failure in first year mathematics. The problem of low participation rates is also examined in some detail. Turning to broader issues, chapters are devoted to curriculum, time allocations, classroom teaching, teacher education, and evaluation. It is here that the bulk of the recommendations are found, for the obvious reason that changes in overall philosophy and approach to science and mathematics education must be translated into program changes before any action can occur.

CHAPTER 2

MATHEMATICS AND SCIENCE IN CONTEXT

The Economic Context

There is little doubt that the developed world is currently in the midst of a social and economic revolution which is as profound as any which has occurred over the past few hundred years. It is not an exaggeration to compare the changes now underway to those of the industrial revolution of the 18th and 19th centuries or the communications revolution of the early 20th century (which is continually being extended by ever more advanced technology).

In economic terms, the ongoing revolution is characterized by several features, including a decline in the importance of resource extraction and of manufacturing, increased internationalization of commerce, and the increase in the importance of the service industries. Indeed, Statistics Canada data show that almost all of the growth in jobs in the 1980s has occurred in the service sector, while manufacturing and resource extraction has continued to decline. Projections prepared by Employment and Immigration Canada[1] show that demand continues to increase in a wide range of service occupations, from nursing and teaching, to retail sales, food and hospitality services.

Part of this shift can be traced to continuing increases in the efficiency with which most basic goods can be produced. Basic food production, for example, continues to occupy fewer and fewer people.

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[1] Canadian Occupational Projection System, **Job Futures: An Occupational Outlook to 1995.** Ottawa: Employment and Immigration Canada, 1988.

In contrast, food processing and service have become major areas of growth. Manufacturing has suffered essentially the same fate. Increased automation of the means of production has led to a sharp reduction in demand for labour. In manufacturing, there is the added twist that it has become much cheaper to move many manufacturing operations to developing countries, where whatever demand continues to exist for manual labour can be met at much lower costs than prevail in developed countries. The increased participation of women in the workforce has also contributed to an increase in demand for external services and goods related to maintaining the household and to child care. Increased levels of education and of leisure time in the general population have resulted in increased demand for travel, hospitality, entertainment, and cultural services.

The growth in service occupations presents a fundamental problem for the analysis of the demand in scientific and technological fields. On the one hand, much of the growth has been in low level non-career occupations, characterized most obviously by the fast food industry. One would be hard pressed to make an argument that such occupations have much to do with increased demand for education in the sciences.

The opposite extreme is illustrated by the increasingly pervasive use of microcomputers in all areas of the workplace. It is essential to recognize that facility with such machines is fast becoming an essential requirement in such a variety of occupations that it is difficult to imagine anyone being untouched by the microcomputer revolution in coming years. While certain uses of such machines are routine, most require levels of skill, knowledge and ingenuity which far exceed previous requirements. In most cases, any routine jobs which have been eliminated have been replaced by much more technologically sophisticated ones, requiring capabilities which far exceed those of the jobs lost. The point may be illustrated by something as simple as the preparation of this report. What the reader sees on the pages of this report, including graphs and charts, was produced directly by the writer, using a microcomputer based text processing system. No clerical or typing assistance was required at any stage of the process. On the other hand, statistical and data management capabilities of the highest order were required to assemble and analyze the data on which the report is based.

As the above example illustrates, the advent of the microcomputer is clearly the signal event in the current revolution. Unlike most previous machines, the microcomputer is not strictly a labour saving device. While reducing the demand for low level clerical and other functions, it has opened up a variety of previously unheard of applications, and has substantially increased the demand for higher level skills. More important, an entirely new industry has been created in the manufacture, sales, and installation of such machines, and most significant of all, in the development of the software required to make them useful. Those unfamiliar with the principles, operations, uses, and limitations of such machines are already at a major disadvantage in the workplace. This disadvantage can only increase with time, unless large numbers of future workers can be educated in such a way that they can adapt to the ever changing environment created by microcomputers.

At a much broader level, the leading edge of most areas of economic activity, from the fishing industry to the development of computer software, from forestry to the provision of health services, involves the application of science and technology to increase productivity, develop new products, or solve problems. In this context, it is now widely acknowledged that knowledge is becoming the most prized commodity in the emerging global economy. Knowledge resides in people, and people are much less mobile than the other means of production. Those societies which are most successful in educating their people to a level which is attractive in the global marketplace are much more likely to be successful economically than those which continue to rely on natural resources or on cheap unsophisticated labour.

The Social Context

By social context, we refer to the conditions necessary to maintain a high quality of life within a particular community. These conditions include political stability, human rights, good health, environmental quality, freedom from poverty, equal opportunity, cultural activity, and a host of other elements. Although economic prosperity is not synonymous with quality of life, the two are intertwined to a substantial degree. Not only is a viable economy necessary in order to provide the means to maintain the social fabric, but also the provision of social services is, in itself, a substantial and increasing contributor to the economy. Indeed, as has already been argued, occupational growth is becoming increasingly concentrated in areas which contribute directly to enhancing the quality of life.

Again, it is not difficult to find examples of the link between science and technology and the conditions which contribute to quality of life. Indeed, it is almost impossible to read a newspaper or watch a television report without encountering such examples. On a global scale, the multiple threats of nuclear war, environmental deterioration, overpopulation, and so on remain with us. Each of these has strong scientific and technological overtones. It may be argued that for every problem solved by scientific and technological knowledge, new ones are created which demand ever more of the same knowledge. Increased sophistication is demanded on the part of the general public, as well as those directly engaged in science based occupations, to understand these issues and to respond politically and socially.

Education holds a unique place in the social setting because it is both an element in itself of a high quality of life, and a major contributor to other elements. Education may be viewed as a desirable good in its own right, in the sense that many areas of knowledge and skill, from athletic ability to art and music, not to mention science, are sought after for their own sake. On the other hand, a high level of educational attainment is necessary both to bring about other desirable ends such as good health at a personal level, and to create the expertise necessary to achieve these ends in the society as a whole. Improved education creates an obvious bootstrapping effect, in that it increases awareness and demand for other quality-of-life services and enhances the capacity to provide such services.

The Newfoundland Setting

The general points made in the previous sections are applicable to any economic and social setting. It remains to ask whether there are any particularly local variations which could affect our thinking about the place of education in general, and mathematics and science education in particular, within the local context.

There is little need to elaborate on the current economic climate in the province. The recent Royal Commission on Employment and Unemployment[2] has presented a cogent analysis of the state of the economy, and particularly the systemic factors which contribute to high unemployment. It has also put forward a model of economic development based on building on the strengths of the existing economic and social system. Improving the effectiveness of the educational system is one of the key elements in this model. In particular, the Commission called for an improvement in the quality of basic education, especially in rural areas, for programs which enhance self-reliance, and for explicit economic development objectives for all levels of the education system. The Commission specifically referred to improved computer education as one aspect of this overall improvement in quality.

More will be said later in the report about the type of mathematics and science education which can contribute most to these objectives. Suffice it to say here that one of the obvious implications is that such programs develop a sense of independent thinking, a sense of confidence in the ability to control one's own life, and a sense of how technology can be used to improve one's own economic prospects and those of the community.

One of the thrusts of this report is to reinforce the principles of self-reliance espoused by the Commission, and to attempt to find ways in which mathematics and science education can be improved along lines consistent with these principles. In a sense, this gives us the first general element in a framework for education in our areas of concern. That is, science and mathematics education should be designed to provide individuals with knowledge and skills which will enhance their prospects for becoming self-reliant and their ability to contribute to the self-reliance of their communities. Fortunately, this goal is entirely consistent with goals which are more commonly enunciated in various analyses of what school science and mathematics are about.

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[2] **Building on our Strengths,** Final Report of the Royal Commission on Employment and Unemployment. St. John's: Queen's Printer, 1986.

The overall argument about the importance of science on a local level may be illustrated by reference to a public debate which has been raging as this report is being written. The debate is about the state of fish stocks, and the recent decision to reduce fishing quotas. This issue is so relevant to the present argument that it bears some elaboration.

This debate is taking place at several levels, all of which are grounded directly in scientific and technological issues. First, there is the question of the credibility of the scientific data upon which the quota decisions are based. Problems of sampling and counting stocks, maintenance versus growth of the resource, calculating maximum sustainable yields, or even knowing the eating habits of seals all impinge on the decisions which must be made. A demand is being made for substantial sophistication on the part of the public, to understand how data on fish stocks are gathered, and how such data need to be continually updated and reinterpreted. This provides a strong argument for scientific literacy on the part of citizens of the province.

Second, there is the issue of whether the inshore or offshore fishery should bear the burden of the quota reductions. This is a classic political and economic issue, with strong vested interests on both sides. However, the underlying issue is essentially technological. It is clear that the offshore sector possesses the technology to catch far more fish than are available, while the technologically unsophisticated inshore fishery is subject to the uncertainties of stock migration, weather and ice conditions, and a host of other factors beyond the control of those involved in the industry. Beyond the political problem of who should get what share of the resource, therefore, is the question of the impact of technology on the most important sector of the local economy, and whether increased technological sophistication is beneficial or detrimental to the economy.

A case can be made that technology, as applied to increased ability to catch the naturally occurring stock, has reached the point of diminishing returns. This brings us to the final level of this debate, which is currently much less prominent. Here the focus shifts away from the immediate problem of stock sizes to the possibility of using aquaculture, or fish farming, to remove the dependency on naturally occurring stocks. From a technological perspective, this presents much more interesting and challenging problems than other areas of technology applied to the fishery.

Worldwide, aquaculture has progressed to the point of accounting for a significant proportion of current fish supplies, especially in the more valuable species. Locally, several operations are in existence. However, few are concerned with the dominant species, cod. It takes little imagination to invent a scenario in which this would change dramatically, in a way which would again make the inshore fishery the dominant part of the industry. One need only think of an extension of a current project, in which small cod from the trap fishery are captured and raised to more marketable size. This is obviously an area in which research, development, and education could merge with the traditional interests and abilities of the people of the province, and in which the province could conceivably become an exporter of knowledge as well as fish.

Taking these arguments to a much broader level, it is generally understood that the basic industries which fuel the local economy have always been vulnerable to a host of factors outside the control of either the industries themselves or public agencies within the province. Events ranging from weather conditions to the state of international markets seem to continually play havoc with resource based industries. Aside from temporary interventions, such as make-work projects, governments have been able to do little to respond to the vagaries of natural events and external economic conditions.

Our own level of educational attainment, on the other hand, is something that is largely within our own control. The state of education in the province is determined by the sum of a host of individual and collective decisions, virtually all of which are made by our own people. If achievement levels are low, as will be shown later in this report to be the case, we cannot attribute this to bad weather, foreign overfishing, international markets, or any of the conditions which affect our basic industries. Similarly, the ability to improve our educational performance is much more within our own control than the ability to change the latter factors. At the most general level, this report represents a plea to make a determined effort to bring about a substantial change in educational expectations, participation, and performance. If the concept of education as an economic catalyst has any merit, the payoff from such a decision can be expected to be an economy which is more attractive to those seeking high level human resources, and which is much less vulnerable to external events.

Science Education in a National Context[3]

Over the past several years, science education has received unprecedented attention at the national level within Canada. Two major national studies have been conducted. Important initiatives have been taken by several provinces to improve the quality of programs. A major federal scholarship program has recently been put in place, in support of a much broader federal attempt to enhance the level of research and development activity in the country. All of this activity attests to the importance of science for national policy, and suggests that activity in this area has transcended provincial concerns and jurisdictions in education.

For our purposes, one of the most important of these activities has been the study conducted by the Science Council of Canada.[4] This study yielded a substantial body of data on goals, programs, teachers, textbooks, and other important elements of the system. This provided a basis for the first broad assessment of the state of science education in the schools.

In the report of this study, it was argued that science education in practice falls far short of the ideals expressed in most statements of aims put forward by the various ministries of education. Shortcomings in curriculum, teaching, and resources were identified and an agenda for renewal was proposed, based on the following elements:

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[3] In broad discussions such as in this section, the term science education may be taken to include mathematics education. In more specific discussions of curriculum, teaching, and the like, it is more convenient to separate mathematics and science.

[4] Science Council of Canada, **Science for Every Student: Educating Canadians for Tomorrow's World.** Ottawa: Supply and Services Canada, 1984.

Science Education for All

1. Guaranteeing science education in every elementary school
2. Increasing the participation of young women in science education
3. Challenging the high achievers and science enthusiasts

Redirecting Science Education

4. Presenting a more authentic view of science
5. Emphasizing the science-technology-society connection
6. Setting science education in a Canadian context
7. Introducing technology education

Monitoring Science Education

8. Ensuring quality in science education

The second major study was conducted as part of the Second International Science Study (SISS), sponsored by the International Association for the Evaluation of Educational Achievement (IEA)[5]. The main thrust of this study was on obtaining comparative measures of science achievement in the participating countries. The Canadian study went well beyond this, however, in examining curriculum and classroom practices and in placing science education in historical perspective. Since the study was not a policy study, no specific recommendations were made. Nevertheless, the study provides a substantial addition to the knowledge base by addressing areas not touched by the Science Council study. In particular, work carried out in Newfoundland gives a detailed picture of classroom events at the junior and senior high school levels.

The data on science achievement were reanalysed by the Task Force, with particular emphasis on providing interprovincial comparisons. A full account is given in **Background Report # 2.** Highlights of the results also appear in Chapter 4 of this report.

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[5] Connelly, F. M., Crocker, R. K., and Kass, H..**Science Education in Canada** (Volume I, 1985: Volume 2 in press). Toronto: OISE Press.

Essentially, the results show that Canada performs well relative to other countries at the grade 5 and 9 levels, but that performance drops substantially by grade 12. Newfoundland's position is at the bottom of the Canadian scale on almost all measures, and compares unfavourably to most countries when examined on the international scale.

Unfortunately, no comparable studies have been carried out in mathematics. An international study along the same lines as SISS has been conducted, but with only two participating provinces in Canada (Ontario and British Columbia). A better picture of achievement in mathematics can be obtained from standardized tests, so no attempt was made to repeat this study for Newfoundland. Obviously, some of the problems of mathematics education in the schools are quite different from those in science, since there is little question that all students receive extended exposure to mathematics. At the same time, most for the basic aims are the same for both areas. For purposes of much of the discussion in this report, science and mathematics can be treated as two aspects of the same area of concern.

The final area of national activity which deserves mention is the program of undergraduate science scholarships recently established by the federal government. This program is designed to attract larger numbers of the best students in the country towards scientific fields. A total of 2500 new scholarships per year are offered, each valued at $ 2000 annually for four years. When the program matures, as many as 8000 students will be funded under this program each year. By any standards, this is a large scale incentive program.

Scholarships are valid only for university undergraduate programs in the basic sciences and mathematics. Applied sciences and professional fields such as engineering and medicine are not eligible, as there is seen to be no shortage of students wishing to enter these fields. A quota of half the scholarships has been established for women candidates, in order to overcome the traditional male domination of the scientific disciplines. Initially, quotas have been allocated to universities, based on the number of science graduates historically produced by each institution. It is ultimately intended to establish a single national competition. However, the form which this competition will take is not yet clear.

Historical and Current Context in Curriculum and Teaching

Most of the mathematics and science programs in use today reflect the legacy of an intensive effort in curriculum development which had its origins in the United States following the launch of the Soviet satellite Sputnik in 1957. The following decade was one of unprecedented developmental activity, which took on all the characteristics of a worldwide reform movement. The essential thrust of the movement was one of designing curricula to reflect the fundamental structure and methods of the scientific disciplines. Also underlying the movement was an emphasis on inquiry, as both characteristic of science and mathematics themselves, and as an essential feature of student learning. This phenomenon was perhaps most visible to the public as the **new mathematics**, although what might be called the **new science** was perhaps even more pervasive in curriculum development work itself.

The driving force behind the curriculum development movement was the scientific community, with the professional associations to which scientists belong playing an important part both in defining the general directions of the movement and, in a number of cases, in conducting the actual developmental work. The curriculum packages which emerged from this effort were, in general, highly abstract in nature, with emphasis on the major theoretical schemes in science and the underlying logical structures of mathematics. Some programs were explicitly process based, and were designed to separate process from its underlying subject matter, to be taught for its own sake. The scientists were highly critical of earlier, more practical curriculums, in which the emphasis was primarily on computational skill, technological applications, and the like. Educators and textbook publishers enthusiastically embraced the views of the scientists, thus ensuring that the movement would have substantial impact on school practices.

Nearly three decades later, it is interesting to reflect upon the impact of this work. The specific curriculum packages, characterized by acronyms such as SMSG mathematics, PSSC physics, S-APA, and so on, which are so familiar to science and mathematics educators, have long since largely disappeared from the market. There are growing doubts as to whether the true spirit of the reform movement ever really penetrated the school system. Nevertheless, it is clear that certain of the major ideas from the era, particularly the ideas of teaching science as process and teaching mathematics in conceptual terms, live on in the curriculums of today. Similarly, teacher education programs continue to reflect the thinking generated in the 1960s. There is no small irony in the fact that scientists and mathematicians are now beginning to speak out in criticism of the state of school programs, in a tone which frequently seems to suggest that educators, rather than their own colleagues of a generation ago, are largely responsible for what some now see as a large scale curriculum failure.

Whatever the long term legacy of the curriculum reform movement, one aspect of this movement needs to be recaptured if progress is to be made towards the next generation of programs. There has been no recent equivalent of the 1960s reform movement in terms the enthusiasm, energy, talent, and resources applied to thinking about school programs. Recent efforts at further reform are proceeding on a minuscule scale by comparison. The current resurgence of concern, while it has generated some research and development, and substantial debate, has not manifested itself in a coherent program of reform, and it is unlikely that the national and international character of the earlier generation of work will be recreated. In fact, it can be argued that one of the reasons for its failures lies in the lack of attention to the local character of educational decision-making, and the importance of teachers in the process. The best hope for further reform lies in the ability of local educational jurisdictions to consolidate the broad ideas which now abound, and make these part of their own attempts at change. The challenge to those operating at a local level is substantial. It can only be hoped that reports such as this will provide some impetus to recreate the best features of an earlier major effort.

If the earlier reform movement is dead, what is now taking the place of its basic underlying principles? It is possible to identify several current thrusts, some of which can be traced to the earlier era, and some of which reflect a new reality which has emerged since that time. The most obvious of these ideas is that captured in the term "science-technology-society." Essentially, what is being conveyed by this term is the idea that students should learn more about the impact of science on society, the scientific basis of technology, and the specific technological developments which are so rapidly transforming society. There is a small but significant body of research, development, and curriculum material based on this idea. Interestingly, much of the impetus for this approach comes not from the United States but rather from Europe, Asia, and Australia. A small number of Canadian researchers and thinkers have also played a prominent part in articulating the basic ideas and in developing examples of curriculum based on these ideas.

A second approach, more directly associated with mathematics, is that of problem-solving. Recent standards for mathematics teaching published by the National Council of Teachers of Mathematics[6] feature problem solving as the fundamental purpose of mathematics programs throughout the elementary and secondary grades. This represents a clear departure from the approach based on the structure of the discipline which characterized earlier programs, and also from the computational emphasis on much mathematics as actually taught or as presented in many textbooks. The type of problems emphasized also represents a departure from the common contrived word problems found in many mathematics textbooks.

A third idea, that of science as process, has been carried over directly from the earlier reforms. It is rare to find today a curriculum guideline which fails to use the process terminology of the highly influential program Science-A Process Approach.[7] What seems to be missing is any clear attempt to place these processes in the context of the natural phenomena they are designed to investigate. Processes (observing, classifying, hypothesizing, controlling variables etc.) have become reified and treated as something like formal mathematics, abstracted from real phenomena. Students may thus be found classifying buttons or measuring in arbitrary units, simply to illustrate the processes themselves. There is reason to question such an approach when phenomena of direct scientific interest abound.

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[6] National Council of Teachers of Mathematics, **Curriculum and Evaluation Standards for School Mathematics.** Reston, Virginia: NCTM, 1989.

[7] American Association for the Advancement of Science. **Science: A Process Approach.** Washington, D.C.: AAAS, 1966.

Overarching all of these is a more general thrust in education towards greater accountability, and increased emphasis on performance. Numerous recent studies,[8] as well as public debate and media comment, provide ample evidence of widespread concern that education has somehow "gone soft", and that the emphasis on participation and on individual independence in learning have been detrimental to the needs both of society for higher levels of attainment and of individuals for more marketable skills.

The emphasis on accountability has been most directly manifested in a return to large scale testing programs in many jurisdictions, and by the use of test results as indicators of system performance as well as of individual student attainment. Obviously, the concerns which precipitated this study were based on just such considerations. Whatever the gains made in other less clearly measurable areas, it is clear that the public has not abandoned, and indeed has begun to reassert, the requirement that schools ensure that students perform at an acceptable level in areas of basic measurable knowledge.

Turning very briefly to the process of teaching itself, one of the most striking features of the past decade or so in educational research has been the progress made in the study of classroom teaching. Observational studies have yielded some solid findings about how classrooms function, why they function as they do, and how to improve the effectiveness of teaching. Although there are many who would challenge the fundamental conceptual basis of much of this research, the results fit well with the increased emphasis on accountability. The fact is that we now know a great deal about what is required to bring about higher levels of academic achievement, if that is what we wish to accomplish. There are some signs that the results of this research are beginning to enter the thinking of the teaching profession, and to influence classroom practices. At the same time, it is necessary to take considerable care in drawing prescriptions for teaching from such results, as there is plenty of evidence of administrative and legislative abuse in defining such things as minimal competencies for teachers and in evaluating teacher performance.

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[8] A recent Canadian example is Radwanski, George, **Ontario Study of the Relevance of Education and the Problem of Dropouts.** Toronto: Ontario Ministry of Education, 1988.

Perhaps the best known American example is **A Nation at Risk: The Imperative for Educational Reform.** The National Commission on Excellence in Education, Washington, D. C.: U.S. Government Printing Office. April, 1983.

Goals of Mathematics and Science Education

The goals of mathematics and science education must be derived from our understanding of the social and economic contexts. Most analyses of goals include the elements of scientific literacy, science for work, science for critical and analytical thinking, and science for citizenship. The narrower element of acquiring basic computational skills, often found in discussions of mathematics education, can be subsumed under the more general literacy theme for purposes of our discussion. In discussing these elements, we draw heavily on the analysis presented in the Science Council of Canada report, while differing on specific points, particularly, on the meaning and scope of scientific literacy.

Scientific Literacy. The notion of literacy has traditionally meant the ability to read, write, and carry out basic numerical operations, at a level sufficient to function in a society which takes such skills for granted. Recent studies of literacy levels, for example, have used such skills as reading a newspaper article or calculating the cost of a restaurant meal as indicators of literacy. Except for basic computational skills, there is little to connect this concept of literacy with anything in science or mathematics. We must therefore ask whether it is possible to develop the concept of literacy in a direction which would include scientific knowledge.

Fortunately, this is a relatively easy task. One only has to ask about the content of newspaper articles or television programs to make the point. From public opinion polls to medical breakthroughs, from developments in communication to expert testimony in legal proceedings, from home entertainment devices to workplace automation, and not least in advertising, the media contain innumerable examples of material which is largely meaningless, or even deceiving, to individuals who have no sense of the scientific basis of many of the claims made. The point is, it is meaningless to talk about being able to read, or even listen, in the context of the public media, without looking at the subject matter which is being read or heard. So much of this subject matter has a scientific basis that the lack of a grasp of basic scientific ideas is as much a mark of illiteracy as the inability to read a sentence.

The Science Council of Canada report takes a much broader view of scientific literacy, based on the idea that literacy should be taken as a composite of the other goals ascribed to science education. Thus, it is argued, scientific literacy encompasses science for citizenship, science for work, science for further education, and science for personal development. While there is little reason to take serious issue with this perspective, it seems to be more straightforward to link scientific literacy more with the more common definitions of literacy, and to address the remaining goals of science education as if they were somewhat independent. More important, it is necessary to address a commonly stated goal omitted in the Science Council's analysis, that of science for critical and analytical thinking.

It was stated earlier that the aim of basic numeracy could be subsumed under the more general theme of scientific literacy. Nevertheless, this issue requires brief discussion, because it is obvious that abilities such as counting, telling time, making basic measurements, performing basic mathematical operations on whole numbers, and the like are fundamental to functioning at even the most rudimentary level in our society. Literacy studies show that there remains a substantial number of people, including some who have been exposed to several years of schooling, who are unable to carry out such basic functions.[9]

The persistence of illiteracy at this level has often been taken as the most obvious sign of the failure of schooling. To do a thorough study of this phenomenon would require a detailed look at areas such as remediation and special education. At the same time, some attention must be devoted to the question, as concerns about an absence of basic skills are not confined to students with special handicaps. An obvious example is the point made in a number of submissions and interviews that the use of calculators in early grades interferes with students' grasp of basic arithmetic operations. Such arguments must be examined, as their impact extends well beyond the realm of special education. Certainly it is necessary to examine the credibility of studies which purport to show that schools have failed to teach even the most basic mathematical skills.

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[9] Creative Research Group. **Literacy in Canada - A Research Report.** Ottawa: Southam News Services, 1987.

Science for Informed Citizenship. Most of the major issues of our time involve, either directly or indirectly, the applications of science. Advances in medicine raise not only problems of the ability of society to finance the procedures being developed, but also major ethical and moral questions. The introduction of technology into the workplace proceeds at an ever expanding pace, including areas (such as offices) long thought to be immune to the sort of displacements once associated with the farm, fishing boat, or factory floor. Technological devices in an almost infinite variety influence patterns of home life, entertainment, travel, and communications. Military applications influence political decisions on a global level. The consequences of environmental degradation become more apparent each day, with science and technology being looked to as both the cause and the potential cure for this problem. At a more fundamental level, issues of scientific research policy, particularly the importance of public support of research, occupy much attention in the political sphere.

Little more needs to be said to illustrate the degree to which science and technology intrudes into all aspects of life. Whether this intrusion is to be in the overall public interest, rather than in the interest of those with the greatest access to scientific knowledge, is one of the primary political problems of our time. There is no way in which this problem can be addressed adequately if citizens are not sufficiently informed about the underlying principles and methods of science, and about the dynamics of the interaction between science and society. In a democratic society, the ultimate decisions are made by all citizens, not just those with the relevant expert knowledge. Whether these decisions are good or bad depends ultimately on the ability of the public at large to understand the issues, and particularly to make judgements in the face of conflicting interests.

Science for Work. While there is some debate over the degree to which schools are responsible for preparing students for work, there has always been some degree of vocationalism in school programs. Indeed, public opinion polls indicate that there is broad public support for such a role. Given the importance of science and technology to so many occupations, it follows that education in science is a key way in which schools can prepare their students for the workplace. In fact, one could go further and argue that even if explicit vocational preparation is not a function of the schools, teaching the basic knowledge necessary to pursue further education which is career oriented is an essential function. Certainly it cannot be expected that institutions devoted to career training would start from the beginning in teaching basic science or mathematics. At this level, science for work essentially becomes science for further education, an objective which is so directly relevant to the work of this Task Force that it requires separate treatment.

A major problem in determining what kind of science education is most appropriate for preparation for work is that entry to the workplace takes place at so many different levels. At the academic and professional levels, for example, what is learned in school can only serve as a foundation for the much more detailed and specialized knowledge which must be acquired in undergraduate and graduate programs. Even at the level of the technologist, several years of post-secondary education are necessary for entry to the workplace. There seems to be little point in arguing that specific vocational education in science is needed at the elementary or secondary level for students planning to enter such occupations. What is necessary is to provide the background which would allow intelligent career choice, a sense that scientific and technological occupations are interesting and challenging, but not out of reach, and a sense of how scientific and technological knowledge is empowering, in terms of the ability to function in the workplace and the community at large. More important, it is necessary for the schools to convey the idea that the well-being of society is becoming increasingly dependent on technological innovation, and that those in a position to contribute to such innovation are likely to be among the most successful in the marketplace. It is here that the link with the idea of self-reliance is most obvious.

Although it is essential to ensure that there is an increase in the number of individuals who pursue scientific and technological careers, there are many more whose careers are likely to involve scientific or technological applications of various sorts, but who are not themselves scientists, engineers, or technologists. One of the striking aspects of change in the workplace is the degree to which new technologies are impinging on hitherto untouched areas. The most obvious impact, as has already been pointed out, has to do with the pervasive use of microcomputers. The journalist, the small business proprietor, the office worker, the tradesperson, the manager, are all likely to encounter such technology at a level which requires the ability to make wise decisions on equipment purchase and use, to adapt to rapidly changing technology, or to find new applications of technology in the workplace. Science education for work must address all of these issues, if those who must work with the products of science are to function adequately beside those whose job it is to produce, maintain, or directly operate the tools provided by technology.

One of the most important aspects of technology in the workplace is the increased demand for access to and control of information. Since those in control of such access can have a significant impact on performance, productivity, and policy decisions, the skills necessary for such access are likely to be required of more and more workers, at all levels. It will no longer be possible for managers or non-technical workers to assume that others will take care of their requirements for information. The skills required for information access and control can serve to enhance the power of all workers. Again, it is the function of science education to convey a sense of the impact of information technology and of the means of putting such technology to effective use.

Science for Further Education. Again, the Science Council report identified this as one of the main goals of science education. This goal is of particular importance here because it is clearly at the interface between secondary and post-secondary education that the problems in science and mathematics education have become the most visible. Unfortunately, it is here that we meet one of the most serious conflicts of opinion about goals. The current thrust of secondary education in the province suggests that the demands of post-secondary institutions should not be an overriding consideration in devising a high school program. In general, the post-secondary institutions seem to be opposed to this view. These institutions expect certain specific knowledge and skills to have been taught in high school. As for the public, there is little conflict. There is overwhelming public support for post-secondary preparation as a goal of the earlier levels of education. However, since there is also overwhelming public support for a wide variety of other goals, it is difficult to judge the priorities to be assigned to different goals from public opinion alone.

Of course, this problem could be easily solved if the kinds of programs most suitable to meet other goals could also coincide with meeting the goals of post-secondary education. It must also be kept in mind that the post-secondary institutions do not represent the end of further education, and that many individuals will find their way into areas which will demand a variety of further education endeavours long after their formal education has been completed. We believe that a core academic program, combined with some degree of differentiation for those most likely to pursue post-secondary studies in mathematics and science, can serve a variety of purposes, and that there is no fundamental contradiction between science for further education and science for other goals. What is required are programs which will explicitly address these goals, and which will ensure that the goals are not lost in the day to day struggle to teach specific details.

Science for Critical Thinking. Most statements of aims of education place critical thinking near the top of the list. The essence of the argument for critical thinking is that students need to acquire the ability to go beyond specific knowledge, and learn to analyze, synthesize, assess the quality of arguments, apply the rules of logic and rational thinking, and ultimately to generate new personal knowledge. In science education, these capabilities have typically been associated with teaching the processes of science: observation, measurement, interpolation and extrapolation, hypothesis formation and testing, and so on. In mathematics, the connection is more directly with formal deductive reasoning, as well as with general methods of symbol use and manipulation. There is a close link between all of this, of course, and the theme of science for citizenship, because these general thinking abilities are precisely the ones required to make intelligent judgements when faced with conflicting arguments, to see flaws in positions, or to distinguish founded from unfounded claims.

Much of the debate in the literature on science and mathematics education centres around whether various approaches to curriculum or teaching can enhance critical thinking skills. Certainly many of the major curriculum developments of the past couple of decades have this as an aim. At the same time, it must be admitted that far too little is known about how to develop such capabilities in students. Because of this, it is not possible to assert with confidence that any particular approach to teaching will be successful. There is plenty of evidence from studies of teaching, however, which indicates that approaches which pay explicit attention to particular goals are more likely to succeed in meeting those goals than approaches which assume that goals can be met implicitly. A fundamental problem in much science and mathematics teaching is that it is all too easy to lose sight of broad goals such as critical thinking, and to fall back on much more explicit and narrow goals such as content coverage. What is needed is to at least make explicit the goal of teaching critical thinking skills.

Although the goal of critical thinking is not unique to science or mathematics, there are contributions which only these subjects can make to achieving these goals. As the Science Council of Canada argues, science is, at base, the study of the natural environment. In exploring the environment, children are essentially emulating the methods of the scientist. What is required is to take a systematic, rather than a trial and error way of learning about these methods, and to seek ways of ensuring that the capabilities acquired through such study can be generalized to new problems.

The NCTM Mathematics Standards

This discussion would not be complete without more detailed reference to the standards for school mathematics recently published by the National Council of Teachers of Mathematics (NCTM). Although there is considerable overlap between the general objectives just described and the goals of mathematics put forward in that document, the NCTM document has developed goals that may be considered as more unique to mathematics. The overriding goal is clearly mathematics as problem-solving, a goal which is closely allied with that of critical thinking. Mathematics as communication, mathematics as reasoning, and mathematical connections are other broad goals to be emphasized at all levels.

More specific goals include number and number relationships, estimation, measurement, geometry, algebra, probability, statistics, analytic geometry, and the conceptual underpinnings of calculus. In some ways, these resemble more closely the topics we are accustomed to seeing in conventional mathematics courses. Nevertheless, it is clear that there is a substantial shift in emphasis in these goals away from computation, and towards estimation, statistical concepts, and other topics more in line with the broad goal of problem-solving. For example, the standards deliberately play down the importance of conventional computational algorithms, in favour of estimation procedures which may be used to judge the plausibility of results produced by calculators. Judging from some of the submissions to the Task Force, this shift is likely to be a controversial one.

Overall, these standards, provide a firm foundation for mathematics curriculum development. More will be said about this in a later chapter. The important point here is that such standards serve to give some substance to general goals. This helps avoid one of the most serious problems which plague most curriculum development efforts, that of the large gap which exists between the high-mindedness of goal statements and the more mundane realities of curriculum guidelines, textbooks, and day to day teaching practices.

CHAPTER 3

STATEMENT OF PRINCIPLES

This chapter sets out what the Task Force believes to be the basic requirements for improvement of mathematics and science education in the province. These requirements take the form of a set of statements of principle. These statements have been derived from several sources, including current thought in science and mathematics education, the goals outlined in the previous chapter, an analysis of public and professional opinion presented to the Task Force, and finally the data available on achievement and participation. Most of the backing for the arguments presented in this chapter is found in the various background reports, and in the three data summary chapters in **Part II** of this report. Some of the arguments are also further elaborated in later chapters on curriculum, teaching, and evaluation. While this leads to some repetitiveness in the report, it was felt that a useful purpose could be served by explicitly stating certain general principles early on, while leaving more operational details for subsequent chapters.

Priorities in Schooling

Some readings of public opinion on education seem to lead to the conclusion that the public wants the schools to do more of everything. Looking beyond the surface features, however, it is clear that the public does not see all school activities to be of equal value. Areas such as language, mathematics, and science are seen to be of higher priority than other areas. Not surprisingly, this view is consistent with the demand for basic literacy, and for ensuring that students possess the necessary skills to function in the social and political setting, as well as in the workplace. Going a step further, it may be argued that there are some things which the schools are uniquely able to do, while other things sometimes expected of the schools could conceivably be handled by other institutions of society.

It is difficult to imagine any institution other than the schools being able to develop in students a high level of knowledge and skill in written language, mathematics, or science. On the other hand, there are many institutions concerned with physical, social, or spiritual development. This is not to say that schools should have no role in the latter areas. It is simply to assert that in the face of increased pressures on the curriculum, schools should place their highest priority on the areas they are best equipped to handle, and that no other institutions are in a position to address. Our first principle is therefore the following:

Not all school subjects are of equal value. Schools should assign their highest priority to teaching the basic academic subjects which they are best equipped to handle, and which are not part of the mandate of other institutions in society. Mathematics and science must be included among the areas of highest priority.

Participation in Secondary School Programs

For the past two decades, one of the primary goals of secondary education has been to offer programs which would encourage students to stay in school until high school graduation. Indeed, it is no exaggeration to say that increasing the holding power of the schools has been the major preoccupation of educators at the secondary level. Academic failure has been widely believed to be a primary cause of students dropping out of school. The most common response to this has been to devise programs which are intended to be more attractive to non-academic students, and in which such students can experience success.

The most obvious manifestation of this in this province has been the revised high school program introduced in 1981. One of the major reasons for the revision was the perception that the previous program was too narrowly academic, and hence too difficult and uninteresting, for many students. Beyond this, it was argued that all students would benefit from exposure to a broader program, and that the increased maturity which would accompany an extra year of schooling would be of benefit, in itself, for post-secondary entrance and entry to the workforce. The revised program imposed new requirements for completion of courses in such areas as culture and democracy, while reducing the minimum requirements in mathematics and science.

Later in the report, we shall examine in more detail the course enrolment patterns which have emerged since the revised high school program was introduced. At this point, we wish to address only the general question of whether there should be a basic core program for all students.

There is considerable irony in the fact that a broadened high school program has been introduced in this province just as other jurisdictions have begun to question the merits of such an approach. Numerous recent studies of education have called for a return to a core academic program. Some have pointed out a fallacy in the argument that narrow academic programs lead to increased dropout rates. One such study in Ontario,[1] for example, has pointed out that dropping out is not confined to those at the lower end of the ability range, and that, in any case, the dropout rate in Ontario remains in the 30 percent range despite more than two decades of a secondary program which is among the broadest in North America.

Many educators now agree that the roots of the dropout problem lie in the early stages of education, and in social and economic factors which lie outside the school system, and not in secondary school programs themselves. This is clearly evident in our school system, where dropping out is much more prevalent in some localities than others, despite the availability of a relatively common program across the province. Beyond this, there is increasing evidence that almost all students at the later stages of secondary education expect to continue their education beyond high school. Indeed, increasing the participation rate in post-secondary education is almost universally seen as both desirable and necessary. Again it is ironic that at such a time high school programs have gone in a direction which seems to reduce the prospects for participation and success in further education.

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[1] Radwanski, George. **Ontario Study of the Relevance of Education and the Issue of Dropouts.** Toronto: Ontario Ministry of Education, 1988.

Overall, there is little to lead us to believe that having to take academic courses is a major contributor, in itself, to dropping out of high school. Even if this were so, it is not obvious that the answer is to devise programs outside the fundamental priority areas in order to give students something they might be interested in or able to handle. The demand in society is not for high school graduates of limited capacity, but rather for individuals with high levels of basic skills and a capacity for further learning. There is an obvious alternative to adjusting programs to perceived limits in student ability and interest. This alternative is to arrange the academic program so that it becomes of more interest, and so that students are more likely to succeed. Given the narrowing of career and further education options which accompanies non-academic high school programs, and the limited expectations and achievement levels which such programs encourage, our second principle must be one which reinforces the importance of core academic areas in the high schools.

High school programs should be designed in such a way as to encourage maximum participation of students in the basic academic courses which open the way to further learning. More specifically, programs should permit a substantial increase in the number of students eligible for admission to post-secondary programs.

What this means in practical terms will be spelled out later in the report. Suffice it to say here that the reference in this report is specifically to mathematics and science courses, even though the same argument can be applied to a variety of other subject areas. It should also be made clear that what is being proposed here is that we abandon the concept of breadth in programs as a goal in its own right, and that we focus the school program on what schools are uniquely designed to do, rather than on current fashions, on what particular interest groups would like schools to do for them, or on what will perpetuate an illusion of success but minimal accomplishment.

Achievement Standards

One of the most obvious features of high school programs as they now exist is the extreme relativism which prevails. The desire to maximize participation in schooling itself seems to have led to the conclusion that it does not matter what is accomplished in school, as long as the students are there for a certain span of years, and can emerge with some form of diploma at the end. This view manifests itself in two ways. First, it is assumed that it is necessary to find programs that the lowest ability students can handle, rather than finding ways to allow such students to handle normal academic work. Second, the evaluation system is designed to ensure that high percentages of students will pass, regardless of their levels of attainment.

One of the most striking aspects of the discussions with teachers and school district officials was the pervasive assumption that large numbers of students are simply incapable of coping with academic work at the high school level. Many, in fact, went as far as to argue that far too many students are finding their way into post-secondary institutions - students who are fundamentally incapable of meeting the demands of programs at that level. Within the high schools themselves, a prevalent view seems to be that unless certain students are allowed to opt for non-academic courses, many will simply become frustrated, fail, and drop out.

Such a view is so pervasive that it might best be described as a **crisis of low expectations.** What is most disturbing about this is the degree to which low expectations are accepted as normal. The result is that instead of students being challenged to achieve at the highest possible levels, the content of courses is adjusted to the lowest levels. Nor is this phenomenon prevalent only among teachers. The Task Force heard numerous cases of students opting for lower level courses, and of programs being arranged so that the final year of high school is an easy year. Success rates in high school, as measured by final marks, and by participation rates are indeed quite high. The question is, what have students managed to accomplish in the process?

As will be demonstrated in a subsequent chapter, the selection of students into advanced mathematics offers a clear case in point of the effect of low expectations. While the advanced mathematics course is viewed as a high risk course, to be taken by only about the top 15 percent of the high school population, the results for this course show an extremely high success rate, indicating that the cutoff point for admission to the course is generally too high. There is little doubt that a substantial proportion of students now in the academic course could succeed if they were placed in advanced mathematics. Selection into the advanced course is more a matter of expectations than of reality.

While there is no disputing that it is desirable to have most students succeed in high school, there is plenty of reason to challenge the assumption that this can be done only through special programs, normative evaluation practices, and other devices designed to lower performance expectations. It is clear that the demands of society are such that those who fail to attain reasonable levels of performance are doomed to play a marginal role in the economic and social system, regardless of whether or not they have completed high school in some nominal sense. In other words, unless we can find a way to ensure that students graduating from high school can be certified as having acquired certain knowledge or skill, then the value of a high school certificate will become debased to the point of being useless.

It is essential, as the first step in improving performance, for the secondary school system to begin to think in terms of what its graduates should be capable of doing, rather than simply assuming that a high school certificate is of value in itself. Instead of continually adjusting programs to meet what is perceived to be a variety of abilities and interests, it is necessary to design programs which will allow success in basic academic areas for most students. It is clearly not acceptable, say, to offer a student the opportunity to opt out of physics or advanced mathematics. What is required is to ensure that students can succeed in such courses. To this end, we state a third principle:

High school programs should be designed in such a way that most students can succeed in basic academic courses. Directing students away from such courses on the grounds of lack of ability is not an acceptable alternative.

Achievement and Participation as Complementary Goals

The idea is prevalent that courses which offer a high level of challenge will inevitably result in higher failure rates, and hence higher dropout rates. While it is true that academic failure is one of the reasons students drop out of school, it is by no means the only reason. Boredom and lack of interest in school programs are as much a problem as failure. Furthermore, much of the decision-making about staying in school is influenced by peer pressure, community expectations, and other factors unrelated to school programs. These factors must be addressed, but these are independent of school programs.

Given the changing aspirations of students, the increasing recognition of the importance of post-secondary education, and the success of the system to date in creating an expectation that students will stay in school, there is reason to believe that increasing the level of challenge in high school courses will not necessarily depress the number of graduates. Furthermore, as will be argued in subsequent chapters, the challenge is to make courses both more rigorous and more interesting, while arranging the system so as to keep success levels high. It follows from this that a fourth principle is needed, which captures the idea that high levels of participation and high achievement levels are not necessarily contradictory goals.

High school programs should be designed in such a way as to ensure that the goals of high participation rates and high levels of performance are complementary. Higher performance expectations need not be imposed at the expense of increasing the dropout rate.

Post-Secondary Preparation as a Goal of High School Programs

One point which is often overlooked in discussions of academic or non-academic courses in high schools is that something like half of all grade 12 students do find their way into post-secondary institutions. Furthermore, something like 95 percent of grade 12 students believe that they will continue their education beyond high school. Even if we remove those planning to enter trades or other programs without high academic demands, we are left with about 70 percent. Whether or not all of these students do find their way into post-secondary education, we are faced with the problem of either closing the post-secondary door to those we judge incapable, whatever their aspirations, or of providing programs which will render these aspirations viable.

Some of those presenting submissions to the Task Force have been of the opinion that we are now accepting more students into post-secondary programs than the system can handle. Others have argued that we are admitting more than are able to cope with the demands of such programs. While there is some justification in both arguments, it is difficult to make a case that fewer people need post-secondary education. The demands of society are clearly in a direction in which education beyond the high school level can be justified for almost all citizens. Furthermore, despite some opinion to the contrary, the public view is overwhelmingly in favour of increased access.

We must therefore solve the problems of capacity, and of student ability to meet program demands, rather than simply balancing the system at its current level or contracting it to a level at which only the very best students have access. Certainly participation rates in this province, despite recent improvements, are far from the best in Canada. If we want our citizens to have the same opportunities, and make the same contributions to society as others across the country, we are far from a position of meeting the total need for post-secondary education.

The argument that post-secondary achievement levels should be improved by imposing more restrictive admissions requirements must be rejected. Instead, efforts must continue to expand access to post-secondary education.

As has already been pointed out, the revised high school program was designed to allow students wider choice, and to increase breadth of exposure, rather than to pursue basic subjects in greater depth. In addition, post-secondary preparation was not considered an explicit goal of the program, except to the extent that it was assumed that students would be more mature on entry. We have already argued in general terms that schools should focus on basic academic matters. This argument is now taken a step further. Given the changing aspirations of students, and society's demand for ever higher levels of educational attainment, it is necessary to make the assumption that most students should be prepared to participate in higher education, and that secondary school programs should facilitate this preparation.

Preparation for post-secondary education should be an explicit goal of high school programs. Most students should be encouraged to select course patterns which will permit entry to post-secondary institutions.

Mathematics and Science for All

It has long been accepted that mathematics should be part of the school program for all students at all levels. Even though it is now possible to graduate from high school without having taken a mathematics course in all years, this rarely occurs. Mathematics is clearly universal up to the end of the junior high school in any case. While we may query the specifics of mathematics programs, we do not have to start with the argument that a full mathematics program is required.

Such is not the case for science. The largest gap in science occurs at the primary and elementary school levels. Despite substantial emphasis on this area in recent years, there is ample evidence that science it treated somewhat haphazardly in elementary schools. At the secondary level science courses are accorded much greater respect, although it is still possible to graduate from high school with only two science credits. Again, this rarely occurs in practice. The largest problem at the senior secondary level is the imbalance among schools in course availability and selection, and the specific nature of some of the courses. Again, these points will be addressed in the chapter on curriculum.

Why is it necessary to argue for mathematics and science at all levels? The reasons are embedded in the goals outlined in the previous chapter. First, the literacy and citizenship goals can be met only through sustained treatment of the subjects. There is more than enough common essential knowledge and skill in mathematics and science to warrant time allocation at all levels. This is especially true for students who will not find their way into post-secondary programs, since the high school will be the last opportunity for these students to attain the required level of scientific literacy. If we are concerned with program relevance, mathematics and science, properly treated, also provide a natural link between school programs and the world around us, particularly the world of natural phenomena and of technology. Finally, and perhaps most important, mathematics and science provide tools for logical and critical thinking.

The tendency to take science seriously only at the secondary level is particularly disturbing in light of most of the reasons why science should be taught. Given these reasons, a much stronger case can be made for science at the primary and elementary levels than at the secondary level. While the more formal approaches possible at the secondary level can convey something of the analytical aspects of science, the driving force of science is still the exploration of the natural world. This world is as real to primary and elementary students as to those in secondary schools. It is essential that students begin their science experience by exploring the natural world, if we are to avoid perpetuating a view of science as an esoteric textbook subject, far removed from reality. If there is a crisis in science education, the focal point of this crisis is in the primary and elementary schools.

Mathematics and science courses should be included in the programs of all students in every year up to the end of secondary school.

Much stronger emphasis should be placed on science at the primary, elementary, and junior high school levels.

Mathematics, Science and the Real World

The essence of science lies in exploring the natural world. This point has already been made, but needs to be kept firmly on our minds as we think about the nature of science teaching. In certain important ways, the same argument also holds for mathematics. However, as mathematics and science evolve, we soon find ourselves going beyond simple everyday phenomena. Elementary particles, black holes, Boolean algebra, and the like do not present themselves to us in everyday settings. Although these are some of the fundamental outcomes of scientific thought and investigation, they are questionable as the subject matter of elementary and secondary science courses, because of their abstract nature. It is particularly important to retain a close link between school science and mathematics programs and the natural world in which these subjects are grounded.

At the same time, it must be kept in mind that modern society encounters science at a second, quite different, level. This level is represented by the technological devices which surround us in all aspects of everyday life. Even the smallest child is exposed to games, toys, home appliances, and other devices which bring advanced science close to everyone. In today's world, particularly in urban settings, such devices are more familiar to most children than stars, animals and plants, rock formations, or other natural phenomena. As for applications of mathematics, we have only to look to public opinion polls, financial data, measurement, computer use, and a host of other everyday applications to illustrate how mathematics also influences modern life, and how mathematical knowledge is essential to function in our society.

All of this leads us to the argument that mathematics and science programs should be grounded in technology and in those problems of society which require mathematical and scientific analysis. These applications give meaning to the leading edge of science, in a way which is impossible through textbook learning of more abstract aspects. There is certainly no shortage of products, data, or problems to use as examples. The challenge lies in integrating these into programs which have become entrenched in the system, and in rethinking the ways in which we teach.

Mathematics and science courses at both elementary and secondary levels should be grounded in problems of understanding the natural world and the world of technological applications.

Success in Post Secondary Programs

It must be made clear from the outset that an approach to teaching which results in failure for half the students entering, as is now the case for first year university mathematics, is fundamentally flawed. While secondary school programs must address the requirements of post-secondary institutions, this in itself will not ensure high success rates. There is strong evidence that instructional approaches in post-secondary courses, particularly those at Memorial University, can stand substantial improvement. The wasted resources involved in having students repeat courses, drop out, take up other courses, and the like should be put to much better use. While any particular success rate target is arbitrary, it is useful to state such a target, in order to avoid perpetuating the myth that some courses inevitably have high failure rates.

Whatever improvements are made in secondary school programs, substantial variation will continue to be found in the entry level abilities of students. Allowances must be made for such variations. Sufficient knowledge is now available about good teaching to ensure that this can be done, and that any desired reasonable level of proficiency can be attained by most students. In arguing for high success rates, therefore, we are not taking the stance that this should be achieved arbitrarily by grade scaling or similar means. Rather, it should be accomplished through improved instruction. The resources required to achieve this will surely be less than those required to deal with the consequences of failure.

Post-secondary courses should be designed to ensure that at least 80 percent of students can receive a passing grade. This should be accomplished by varying instructional techniques, time allocations, textbooks, prerequisites, and other program elements, to suit the circumstances of a particular subject or student group. This objective should NOT be accomplished through grade scaling or through high selectivity.

Special Provisions for Talented Students

One of the consequences of having to design programs to ensure high success rates for large number of students is that something is likely to be lost for those few students who show exceptional talent in mathematics and science. These, of course, are the individuals who must be attracted to advanced studies and to scientific and technical careers. At the moment, we are not graduating sufficient individuals in the basic science disciplines and in mathematics to sustain any momentum which may be generated towards improved scientific performance. In particular, not enough graduates are being produced in such areas as physics and chemistry to fill the demand for high school teachers. The next decade will see a substantial expansion in the demand for scientific personnel, including teachers. If we fail to attract sufficient numbers to the field, there will inevitably be a substantial deterioration in our scientific capacity and ultimately in our quality of life.

Individuals with special talents in mathematics and science should be identified early in their school careers, and encouraged to develop their talents through special programs. At a later stage, incentives in the form of scholarships should be made available to encourage undergraduate university studies in mathematics and science.

Participation of Women in Mathematics and Science Programs

Data presented in the next two chapters will show that, while there is relatively little gender imbalance in either participation or achievement at the high school level, women are severely under-represented in most science based programs at the post-secondary level. The main exceptions are medicine, where there has been a substantial shift in favour of women in recent years, and nursing, which remains almost exclusively a women's occupation. Two issues are at stake here. First, there is the fundamental principle of equality of access to programs for both men and women. Second, it is obvious that women represent a large potential pool of talent for recruitment to areas such as physics and chemistry, which have traditionally had low participation rates. Performance and participation levels in high school courses are now such that young women are in as good a position as young men to enter such programs. However, further encouragement is needed for women to break away from traditional programs and careers. The sort of turnaround which we have seen in medicine is obviously required for most other scientific fields.

Further steps are required to encourage the participation of women in most science based post-secondary programs.

PART II

BASIC DATA

CHAPTER 4

HOW WELL ARE OUR STUDENTS DOING?

It is important not to lose sight of the fact that this study was established on the presumption that students in this province are not performing as well as they should in mathematics and science. Some evidence to support this presumption was available at the outset, in the form of declining success rates in post-secondary mathematics courses. However, no comprehensive review of levels of achievement had been conducted prior to setting up the study. One of the first concerns of the Task Force was, therefore, to document as carefully as possible achievement levels in mathematics and science, and to judge whether these levels are, indeed, unsatisfactory.

The question "how well are our students doing?" is obviously an appropriate one for the public to ask, given the high levels of public support of education. Although test scores are almost universally used to judge individual student performance, there is often considerable reluctance on the part of educators to use such data to measure the overall productivity of the system. Nevertheless, test results are among the few bench marks available for this purpose. While we must recognize that tests have their limitations and that test results are easily misinterpreted, educators must also appreciate that the public's desire for simple and straightforward indicators of educational outcomes should be satisfied. If test results are useful in judging students, then they should be no less useful in judging the productivity of the system. What is important is to report results in such a way as reduce the possibility of misuse.

This is what this chapter is intended to accomplish. First, certain issues in interpreting tests results are examined. A brief summary of test data from a variety of sources is then presented. These data have been condensed from the more detailed summary given in **Background Report #1**. The emphasis here is on whether these results show a consistent pattern. Finally, a judgement is made on whether the results support the presumption that achievement levels in this province are lower than they ought to be.

Data Sources

After examining the available data on mathematics and science achievement, the Task Force concluded, with considerable relief, that the achievement record was reasonably complete, and that it would not be necessary to undertake a full scale achievement testing program as part of the investigation. At least some data were available for all levels of the system. In a number of instances, performance could be traced over a considerable number of years. In others, comparisons could be made of our performance relative to national and international standards. Some of the gaps in the data base were filled by small scale testing programs, involving samples of students in Newfoundland and British Columbia.

The chapter examines data from three main sources; 1) the Provincial Public Examinations, 2) the Canadian Test of Basic Skills administered by the Department of Education, and 3) student records from Memorial University, the Cabot Institute, and the Marine Institute. In all these cases, historical records exist extending over a decade or more. However, except for the Canadian Test of Basic Skills, no comparative information is available. There is no direct way of knowing, for example, whether students from other educational jurisdictions would do better or worse on our public examinations, or how our students would perform on similar tests from other jurisdictions.

In addition to the main data sources, several further sets of achievement data were available. In 1984 a large scale science testing program was carried out in Canada, as part of an international study of science achievement. International comparisons have recently been published by the International Association for the Evaluation of Educational Achievement (IEA).[1] The main results for Canadian students are in a document about to be published.[2] A special supplementary study giving Canadian provincial comparisons was prepared by the Task Force (**Background Report #2).**

A second source of supplementary data was a mathematics test administered to incoming first year students at Memorial University, the Cabot Institute, and the Marine Institute in September, 1988. This test was intended as a diagnostic instrument, designed to detect specific areas of weakness in student mathematical backgrounds. Its primary value for this study was to provide an indication of student facility with a variety of basic mathematical operations, some of which had been taught several years earlier. Some data were also available on the performance of a sample of students in Ontario on the same test, thus adding to the comparative picture.

In order to gain further insight into comparative performance, two specific small scale testing programs were initiated by the Task Force itself. The first used a science test designed by the Department of Education and administered to all grade 6 students in the province in 1987. This test was administered to a sample of students at the beginning of grade 7 in both Newfoundland and British Columbia. In turn, a similar test designed in British Columbia was administered to a sample of grade 8 students in this province. This reciprocal approach to testing was intended to yield more specific comparative data than is typically available.

Interpreting and Using Test Results

Test scores may be examined at two levels. The most common is that of an individual student. Student grades are used throughout the system, for diagnosis and placement of students, reporting to parents, promotion, admission to post-secondary education, and a variety of other purposes. The second level is that of a group. Group results are most commonly used for judging the performance of some part of the system - a school, a teacher, a whole province, and so on. For purposes of this report, only group results are of interest. It is important to recognize, however, that test performance has a substantial impact on the fate of individuals. Behind the various summary statements about how well or poorly students are doing are innumerable individual stories about how test performance influences progress through the system, career decisions, earnings, self-esteem, and other important aspects of individual lives.

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[1] International Association for the Evaluation of Educational Achievement. **Science Education in Seventeen Countries: A Preliminary Report.** London: Pergamon Press, 1988.

[2] Connelly, F.M., Crocker, R.K., and Kass, H. (Eds.). **Science Education in Canada: Volume II, Achievement.** Toronto: OISE Press, (in Press).

It is necessary to recognize from the outset that test scores, or any other measures for that matter, have no meaning in themselves. Scores must be interpreted with respect to some reference point which will tell us whether a particular number indicates high or low performance. In measurement theory, there are two kinds of reference points, commonly referred to as criterion-based and normative. Understanding the distinction between these two is a key element in avoiding misinterpretation of the data to be presented.

A criterion-based measure is one in which some form of standard or expectation is established, based in the body of knowledge or skill being measured. An example would be a driver's test, in which candidates are expected to be able to possess certain knowledge (rules of the road and the like) and be able to perform certain specific tasks (such as parallel parking) before a driver's license is issued. For the individual, passing or failing the test determines whether or not one can legally take a motor vehicle on the road. At a group level, the number of candidates who can pass the test on the first try might be used as a measure of the adequacy of driver education. What is most important about such a test is that no prior judgement is made on the number who will pass, and no adjustment of the test criterion is made to ensure that more or fewer people can pass.

This seems so straightforward that one might ask how there can be any other interpretation of a test result. Nevertheless, school achievement test scores are frequently interpreted from a second point of reference, namely "how well does a student or group of students perform relative to others who might take the test?" The term normative or norm-referenced comes from the fact that the reference point for judging performance is not based in the subject-matter itself, but rather in a comparison among those taking the test.

Most standardized achievement tests are of the normative type. In fact, such tests are typically interpreted in relation to a set of "norms", developed by using the test first on some representative reference group. Student scores can then be spoken of as being above or below the norms. Although the tests may be based on a clearly defined body of knowledge, the interpretation of the results is independent of the actual levels of performance. The Canadian Test of Basic Skills, for example, yields scores which can be compared to the scores of a representative national sample of students at the appropriate grade level.

Although these may seem to the public to be merely technical points, it is important to recognize that trends over time and comparisons of our students with those in other localities are essentially normative rather than criterion-based. We can learn from these results how well we are doing relative to others, or relative to past performance, but not how well we are doing relative to an established body of knowledge. On the other hand, we would expect student grades in high school or university courses to be criterion-referenced, in the sense that a mark should tell us something about the subject-matter knowledge of the student, rather than simply how well the student performs relative to others.

These points may be looked at in the immediate context of public examinations and post-secondary grades. It is generally assumed, for example, that when the Minister of Education announces in August of each year that 89 percent of students have passed the public examinations, this means the schools have been highly successful in their task of bringing students to an acceptable level of performance for high school graduation. At the opposite extreme, when Memorial University announces that only 40 percent of students have been able to pass the basic first year mathematics course, it is assumed by many that this is a mark of failure of the high school system. Obviously, both conclusions cannot be true. The apparent contradiction is removed when we realize that one announcement is based on a normative and the other on a criterion-based interpretation of test results. Recognition of this point is essential for our analysis.

It might be argued that the use of 50 percent as a pass mark, as is done in most school testing situations, amounts to a minimum expected performance criterion. One of the problems, however, is that test scores are often subject to various forms of explicit or implicit scaling, to ensure that a particular proportion of students can get at least 50 percent. For example, the test itself might be constructed at a level of difficulty which ensures a certain percentage of passes, or the marking system might be based on an expectation that the test should yield a certain average score. This immediately converts what might be a criterion-referenced test into a norm-referenced test.

Several other problems also arise when test scores are examined across jurisdictions or over time. One of the most common arguments about the use of standardized tests is that their validity may be less in some localities than in others, because of local cultural or curricular factors. When comparisons are made using non-standardized tests (such as public examinations or university grades) one has to be concerned with the stability of the tests themselves and of the marking schemes used. For example, before concluding that the drop in pass rates in recent years represents a real decrease in performance, it is necessary to be satisfied that the tests have not changed over time. What is important is to attempt to distinguish real changes in student performance from mere artifacts of the testing situation. This is sometimes an exceedingly difficult task.

The Department of Education Standards Testing Program

Every year since 1974, the Department of Education has administered the Canadian Test of Basic Skills to all students at either grade 4, 6 or 8. A high school version of the test has also been administered on several occasions since 1982. This program, known as the Standards Testing Program, has become one of the most widely used indicators of the performance of students in this province.

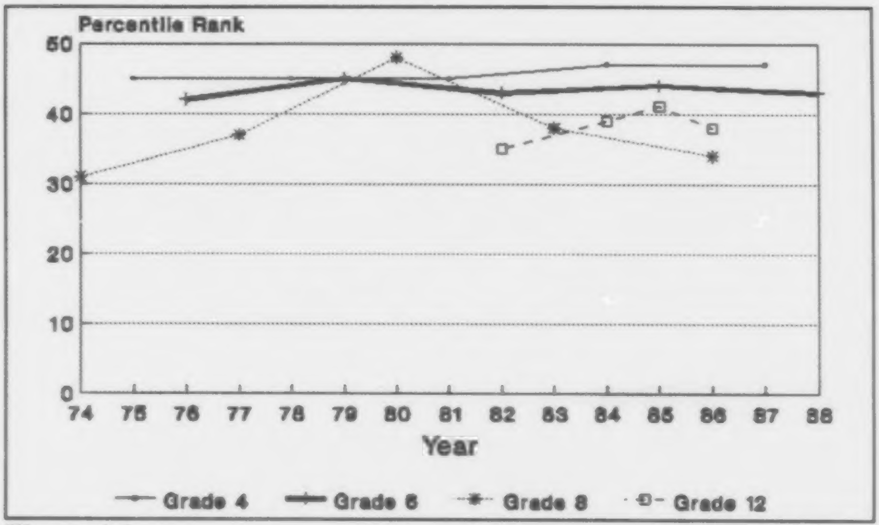

Figure 4.1
CTBS Mathematics Trends, 1974-1988

The Canadian Test of Basic Skills is a norm-referenced test battery, with subtests in vocabulary, reading comprehension, language, work-study skills and mathematics. The test has been normed using a representative sample of students in Canadian elementary and intermediate schools. Scores for Newfoundland students are commonly interpreted with reference to these Canadian norms.

Although there have been arguments over the validity of such a test for use in this province, and over the particular mix of knowledge and skills included, the CTBS has become almost as much of a fixture of the system as the public examinations. Because the test itself has remained stable, and because normative data are available, the CTBS is more useful than the public examinations for comparative and time series analysis.

The data presented here are drawn from annual reports on the CTBS prepared by the Department of Education. (A more detailed summary appears in **Background Report #1.)** Obviously, the main interest here is in performance in mathematics. The relevant data appear in Figure 4.1: the scores plotted are percentile ranks relative to the national student norms for the test. Students in this province would be at the 50th percentile if their average performance was equivalent to that of the norming group. Ranks below this level indicate lower performance than that of the norming group. For example, a percentile rank of 40 on these graphs means that the average student in this province performs at the same level as a student ranked 40th out of 100 in the norming group.

The patterns in grades 4 and 6 are very similar, showing stable performance at about the 45th percentile. The detailed report indicates that performance has been slightly more stable in mathematics than on other parts of the test. In particular, a slight drop in the composite score encountered in the early 1980s does not appear in mathematics.

The grade 8 results are quite different from those in the earlier grades, showing a substantial increase up to 1980, followed by a dramatic decline since then. (This trend holds in other subtests, as well as in mathematics.) Overall performance relative to the norms has never approached that for the earlier grades, and is now only slightly above the level reached in 1974.

The interpretation of these results is complicated by the fact that the CTBS was renormed in the early 1980s. That is, a new sample of students across Canada was drawn, the tests readministered, and new percentile ranks calculated. The results up to 1981 are reported relative to the old norms, while those since that time are relative to a new set of norms. (Unfortunately, there is no convenient way to rescale the recent tests to the old norms.) The implication of this for the interpretation of the trends shown is that performance of grade 8 students in this province, though improving relative to a Canadian population group of some years earlier, had actually declined relative to the general population of students in the country in subsequent years. In short, we have been improving, but others have been improving at an even faster rate. While there may be some reassurance in noting that there has been no general decline in absolute performance on the tests (the exception is grade 8 since 1983), it is not very comforting to realize that we have made essentially no progress in catching up to national standards since the early 1970s. At no time, and at no grade level, has the performance of students in this province been up to the Canadian average.

On the surface, the trend for the high school version of the CTBS is somewhat more positive than that for other levels. In particular, a substantial improvement in performance can be noted between 1982 and 1984, although there was a slight decline in 1986, the last year the test was administered. As it happens, the improvement coincided with the introduction of the revised high school program, and has been used by some as an indication of the success of that program. However, it is difficult to draw any kind of causal conclusion from events which simply coincide in time. More significant is the fact that students in this province have never achieved above the 40th percentile on the high school test. Overall performance mathematics performance at the high school level remains relatively lower than that in the earlier grades.

Overall, these results do not present a very reassuring picture of achievement standards. At best, achievement is remaining steady at levels several percentile points below the national level. Achievement is worse in the higher than in the lower grades. Particularly disturbing is the evidence that grade 8 students are falling further behind their national peers. If this trend holds at the high school level following a further renorming of the CTBS (results should be available later in 1989), then students in this province are likely to have serious difficulty competing with their counterparts across the country in an educational environment characterized by ever greater attention to comparisons on a national, and even international, level.

Public Examinations and High School Certification

Provincial public examinations have been a fixture of the education system in Newfoundland since before the turn of the century. Originally set and marked in England, the examinations have undergone several transitions over the years. However, the basic purpose, that of certifying students for high school graduation, has remained the same. The current system, in place since 1971, is one in which examinations are administered in all final year high school (Level III courses in the current parlance) courses. Some 33 subjects are examined in all. The public examination contributes 50 percent to a student's final grade in a course, with the remainder of the marks coming from school-based evaluations. When the data from the two sources are compared some interesting patterns emerge.

On the surface, the public examinations would appear to be criterion-referenced, in the sense that they are based on a specific body of curriculum content. However, a number of elements in the setting and marking of the examinations suggest that they should more properly treated as norm-referenced. More will be said on this point later. For the present, it should be noted that the examinations are most useful for comparing individual students, or groups of students within a given year. Comparisons over time are more suspect, since there is no mechanism to ensure that the tests are stable from year to year. Time trends are nevertheless presented in the graphs which follow, to illustrate certain important differences between these trends and those based on other data sources.

Basic Trends, Mathematics. Since the revised high school program was implemented, senior high school mathematics has been offered under a three-level system, with courses commonly referred to as advanced, academic and basic mathematics. In concept, this represents only a slight departure from what was in place in the previous program. However, the revised program brought a substantial change in scheduling and in the way in which credit is given for mathematics.

At each level of content, a three-course sequence is available. Each course carries two credits towards high school graduation requirements. Both academic and advanced mathematics have been acceptable for entry to post-secondary institutions. Although students can graduate from high school with only two mathematics credits, in practice almost all students take more than the minimum required. Academic mathematics is the most popular course, being taken by about 70 percent of the students at the grade 12 level. Advanced and basic mathematics are each taken by about 15 percent of grade 12 students.

Figure 4.2 shows the trends in pass rates for academic and advanced mathematics over the past decade. It should be again noted that these pass rates represent a composite of school and public examination marks. It is obvious from these data that the trend in marks has been quite stable over the years. Success rates in advanced mathematics are extremely high, with nearly 100 percent of students passing. This obviously belies the notion that this is a high risk course,

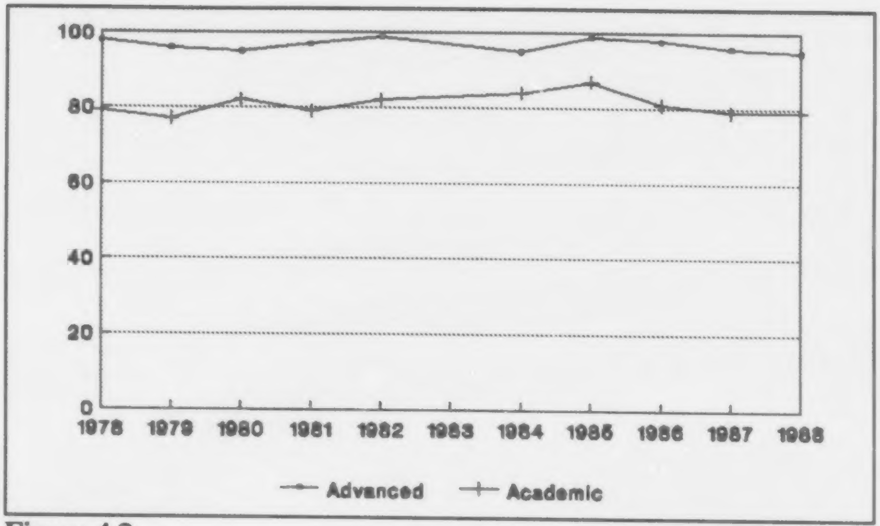

Figure 4.2
Percentage Passing High School Mathematics Courses, 1978-1988

a point which is of considerable importance for later analysis. As for academic mathematics, pass rates are somewhat lower, and slightly more variable, than those in the advanced course. In particular, a slight decline in success rates can be detected over the past four years, following a comparable period of increase. Overall, the success rate in this course is now almost exactly the same as it was a decade ago.

Basic Trends, Science. In terms of course content and structure, the revised high school program had little impact on the main science courses. The existing two course sequence in grades 10 and 11 was simply divided into a pair of two-credit courses at the 2000 and 3000 levels. In fact, few changes have taken place in these courses in the past decade. The main differences arising from the revised program were in sequence and scheduling. Under the revised program, courses can be taken in any of the three years. In the case of biology and physics most schools allow the courses to be taken in either order. This is generally not true in chemistry, where there is a clear hierarchy of topics. Students may also take only one of the courses in a subject in any given year, thus allowing for broader sampling of the available subjects. As is the case in mathematics, students generally take more

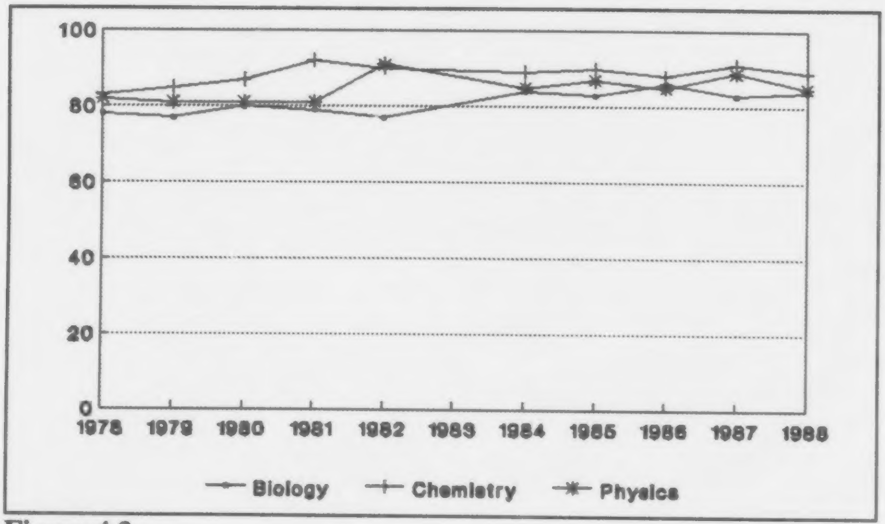

Figure 4.3
Percentage Passing High School Science Courses, 1978-1988

than the minimum of two science credits required for graduation.

Figure 4.3 gives pass rates for the three main science courses offered at the high school level. As can be seen, the general pattern is similar in all subjects. Although small fluctuations have occurred over the years, the general tendency has been towards a slight increase in success rates. Pass rates are more than 80 percent in all subjects.

School and Public Marks. An important issue in a shared evaluation system is whether the schools and the public examinations should attempt to measure essentially the same attributes, or whether schools should assign marks for performance in areas which cannot be adequately measured by tests such as the public examinations. This is particularly important in such subjects as the sciences, where there are areas of knowledge and skill which are not well measured by paper and pencil tests. While the policy on this issue is not entirely clear, our investigations show that most of the marks assigned by the school are given for performance on tests which are very similar to the public examinations. Indeed, most teachers have argued that as long as public examinations exist, they are obliged to reflect these examinations in their own evaluative practices in order to enhance their students' chances of success on what is still seen as the most important measure.

In light of this, it is instructive to compare the marks given by the schools to those attained by the students on the public examinations themselves. A simple comparison of mean scores for mathematics and science courses for 1988 is given in Figure 4.4. As can be seen, school and public marks track each other closely across subjects. However, school marks are consistently about 10 points higher than public examination marks. This pattern also holds for other subjects, and has been quite consistent over time. Clearly, teachers judge their students to be somewhat better than the public examinations reveal. At the same time, more detailed studies show the two sets of marks to be generally quite highly correlated, indicating at least that teachers rank their students in a similar way to the public examinations.

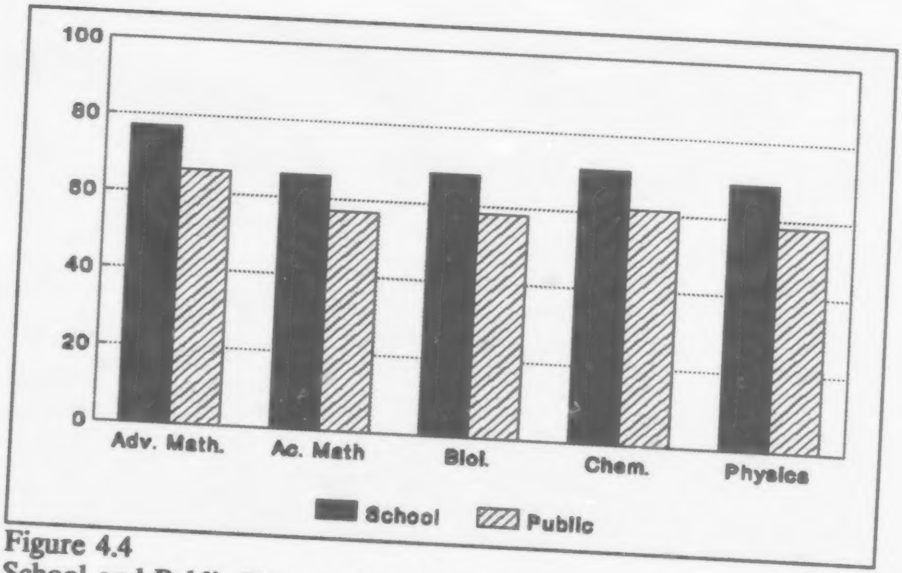

Figure 4.4
School and Public Examination Means,
Mathematics and Science Courses, 1988

University Achievement

This section examines the data underlying one of the core issues for the Task Force - the perception that performance in first year university mathematics and science courses has declined dramatically in recent years. If this is so, then the obvious indicator would be the trends in final grades in the appropriate courses. Again, however, it must be kept in mind that grades can never be taken at face value. It is necessary to ask whether they have been assigned under normative or criterion-referenced assumptions, and whether courses, examinations, and other features of the system have been stable over time.

Basic Trends: Mathematics. For the past several years, until the Fall of 1988, the basic first year mathematics program consisted of a two course sequence, Mathematics 1010 and 1011. Mathematics 1010 was a pre-calculus course, covering topics in advanced algebra and analytic geometry, and included basic concepts necessary for entry to the first calculus course, Mathematics 1011. Students from the high school advanced mathematics course were given a different sequence, with introductory calculus in the first semester. In addition to these courses, a non-credit foundation course was available for weaker students, and a special course was offered for students intending to become primary or elementary teachers. By far the largest proportion of students enroled in the Mathematics 1010/1011 sequence.

Course structures changed in the Fall of 1988. The basic first course, now called Mathematics 1080, is essentially a course in differential calculus. Integral calculus is introduced in Mathematics 1081. An advanced sequence, Mathematics 1000 and 1001 is available for students from the Advanced Mathematics course in high school. A non-calculus sequence, Mathematics 1050 and 1051 is now available, replacing the former 1150/1151 for elementary teachers. These courses are now open to other students, and the content has been changed substantially, emphasizing topics such as probability and statistics. The foundation course has been retained, but is not heavily subscribed.

The trends in performance in the basic Mathematics 1010/1011 for Fall and Winter Semesters are shown in Figures 4.5 and 4.6.

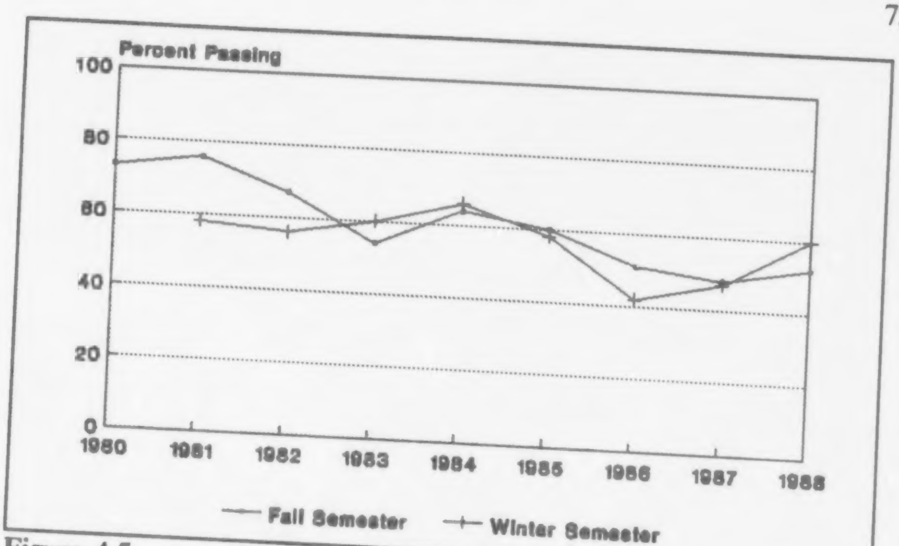

Figure 4.5
Percentage Passing Mathematics 1010, 1980-1988

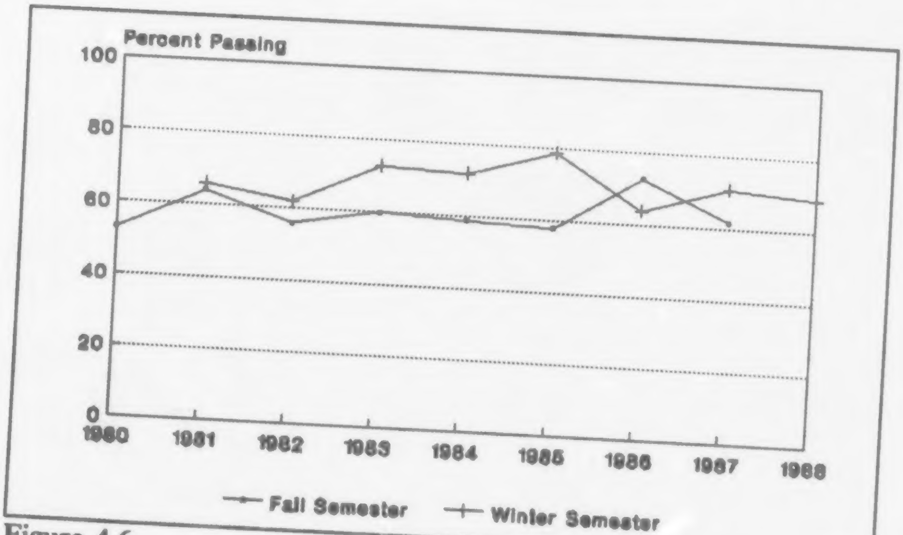

Figure 4.6
Percentage Passing Mathematics 1011, 1981-1988

The major features of these graphs may be summarized as follows:

1. On average, only about 60 percent of all students over the period examined have been able to pass these courses. This is much lower than the 80 percent or more generally found in first-year courses.

2. A substantial overall decline in success rates has occurred in Mathematics 1010 for Fall Semesters. Winter semester results show substantial fluctuations over two or three year periods. In general, however, Winter Semester results have been worse than those for Fall, except for the past couple of years, where a noticeable improvement has occurred.

3. Mathematics 1011 shows a fluctuating pattern of success from year to year, but no distinct trend towards decline. Fall Semester results are generally worse than those in Winter Semester. Again, overall success rates are substantially lower than those for other first year courses.

One or two straightforward observations may be made about these trends. First, the difference between Fall and Winter results is likely explained by differences in the type of students taking the course in the two semesters. Winter semester students in Mathematics 1010 are more likely to have failed the course earlier, or to have come to the course through some unusual route. The reverse is true for Mathematics 1011. Winter students are more likely than Fall students to be those who have succeeded in Mathematics 1010 the previous semester. The absence of a decline in Mathematics 1011 is also likely accounted for by the screening effect of Mathematics 1010. These are natural consequences of course sequences, and are not, in themselves, matters of great concern. The main issues are the overall poor success rates and the decline in success in Mathematics 1010.

Basic Trends: Science Courses. It is difficult to describe in detail the full range of course structures in the science departments. Some departments offer only a single two course sequence for first year students, while others offer differentiated courses depending on student entry characteristics (e.g. whether or not the student took a course in

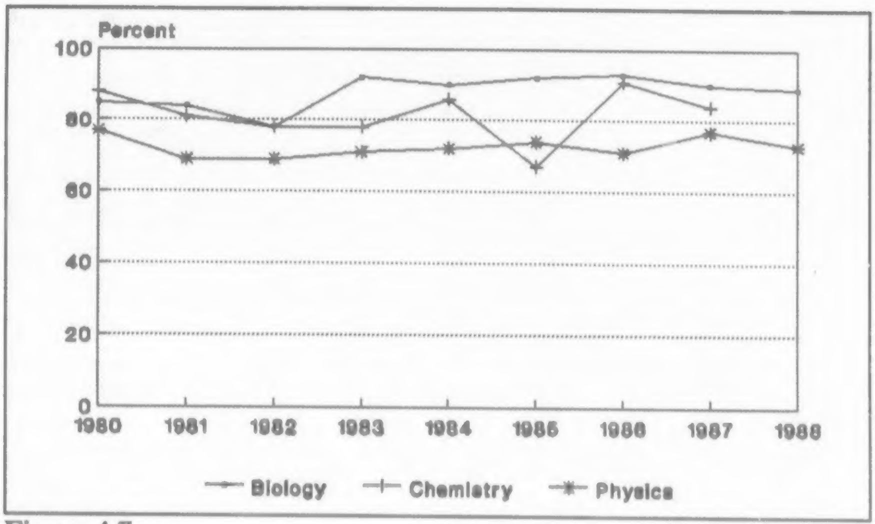

Figure 4.7
Percentage Passing Selected MUN Science Courses, 1980-1988

the subject in high school) and on student destination (e.g. some departments offer special courses for science majors, pre-medical students, and so on). For simplicity, only the courses which enrol the largest numbers of students in the basic subjects of biology, chemistry, and physics are included in this analysis.

As Figure 4.7 shows, the results for the science courses are quite different from those for mathematics. Performance appears to have been at least constant, at levels generally higher than for Mathematics. Biology, in fact, has enjoyed an improvement in pass rates since the early 1980s. Chemistry has fluctuated somewhat in recent years, but is now at a level almost exactly as it was in 1981. The lowest levels of success are in physics, but even this subject is stable at a pass rate of about 75 percent - as high as that for mathematics at the beginning of the decade and much higher than current levels in the latter subject.

It is important to recognize that there are some major differences between mathematics and these other subjects. First, mathematics is, for all practical purposes, a compulsory subject. (Regulations do allow a student in a regular B.A. program to opt out of mathematics, but few do so because mathematics is a prerequisite for so many other programs.) Although enrolments are quite high in all the other science courses, students' degree options are not as restricted by opting out of, say, physics, as by choosing not to take mathematics. Second, mathematics courses are much more dependent on high school prerequisites than those in other subjects. In fact, many instructors in science subjects have argued that it matters little whether or not a student has taken the subject in high school. Most agree, however, that facility with mathematics is essential, especially in physics and chemistry. Problems with high school mathematics, more than with the sciences themselves, are thus seen as the source of problems in first year science.

Results for other Post-Secondary Institutions

It was not possible to carry out such a detailed analysis for institutions other than Memorial University because all of the required data were not available. Nevertheless, some trends could be examined based on data from the Cabot and Marine Institutes.

Course structures at these two institutions are somewhat different from those at the university. Rather than offering one or two common courses, these institutions have maintained a practice of tailoring courses to each specific program. While there is a great deal of common content in these courses, each is taught to a distinctly different group of students. The overall level of these courses is judged to be somewhat lower than that of first-year university courses. It is not necessary to pursue at this point the details of course content. It suffices to examine one or two examples of trends in success rates. Again, these are given in much more detail in **Background Report #1.**

Trends for in a selection of programs at the Cabot Institute are given in Figure 4.8. These trends are representative of what is occurring throughout. Mean scores rather than pass rates are given because the latter data were not available. In all cases some decline is evident over the period examined. On average, the decline has been of the order of 10 percent in mathematics and 20 percent in physics. Chemistry appears to have recovered slightly, following a decline in the mid-1980s. Overall, means have declined from the 65 percent range in the early 1980s to just over 50 percent in the past couple of years.

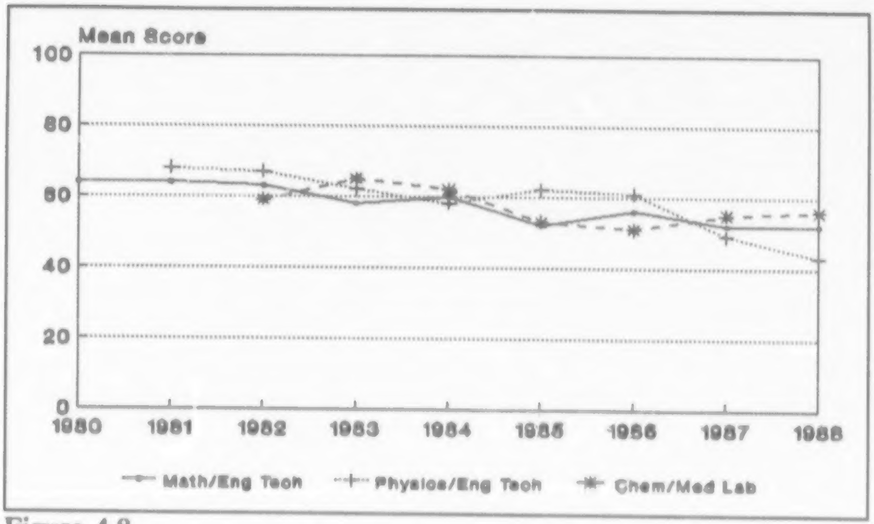

Figure 4.8
Trends in Selected First-Year Courses, Cabot Institute

Data are available only in mathematics for students at the Marine Institute. Each year since 1981 this institution has administered a test of basic mathematics skills to all students entering technology programs. Mean scores are also available for first year mathematics courses. In the latter case, a composite across all courses was calculated because the number of students in each program is relatively small. Trends for both of these sources of data are presented in Figure 4.9.

Unlike the university and Cabot Institute, there is no evident decline in final scores for Marine Institute students, even though there is an indication of a slight decline in entry level mathematics performance, as measured by the entrance test.

International Science Study

In the Spring of 1984, science achievement tests were administered to students in grades 5, 9 and 12 across Canada. This testing program was part of a comprehensive study of science education

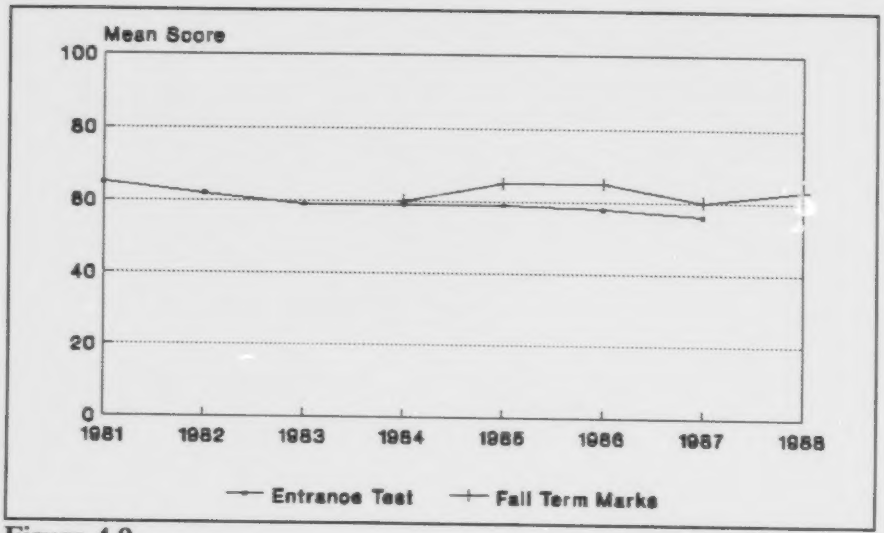

Figure 4.9
Mathematics Performance Trends, Marine Insitute, 1981-1988

in Canada, conducted as part of an international study sponsored by the International Association for the Evaluation of Educational Achievement (IEA). Although the study was originally designed for international comparisons, it was also possible to use the data, with permission from the appropriate jurisdictions, to make comparisons across provinces. A full report, giving both international and interprovincial comparisons, was prepared by the Task Force **(Background Report #2)**. The results of this study are far too detailed to present here in graphical form. The main findings may be summarized as follows:

1. Canada attained a comparatively high level of achievement at the grade 5 and 9 levels, ranking sixth and fourth respectively out of seventeen countries. The top ranked country in grade 5 was Japan, while Hungary achieved that distinction in Grade 9 (with Japan second).

2. In the final year of high school (grade 12 in most countries), Canada's ranking dropped to eleventh in biology and physics and twelfth in chemistry among thirteen countries.

Differences between countries were much larger at this level than for grades 5 and 9. The countries with the highest levels of performance at this level tended to be those which follow the British system of specialization at the high school level (England, Hong Kong, Singapore), and which have relatively low participation rates in these courses.

3. Interprovincial comparisons show that Newfoundland students ranked the lowest in Canada on almost all measures. In international terms, Newfoundland students would have ranked eleventh among 18 countries in grades 5 and 9, and lower than all other countries on all tests at the grade 12 level. In many ways, the results at the lower levels are even more of a cause for concern than those for grade 12, because the highest scores at the latter level were attained in countries which make quite different selection and programming decisions for senior high school students.

The international study has been criticized on the grounds that the achievement measures used are limited to a small common set of items on which an international panel could agree, and that such items may be much more representative of curriculum content in some countries than in others. An alternative interpretation, however, is that the measures represent a common core of science knowledge that all students might be expected to possess, regardless of country or educational system. The comparisons within Canada are perhaps more revealing than the international comparisons because an argument can be made that students across the country will ultimately be competing in a common market. If the achievement differences are indeed accounted for by curriculum differences, there is as much reason to argue for increased commonality in curriculum as for dismissing the results on the grounds of curricular bias.

Mathematics Inventory Test

In September, 1988, Memorial University, the Cabot Institute and the Marine Institute collaborated in administering a mathematics achievement test to incoming first-year students. The instrument used was developed by a community college in Ontario (Fanshawe College in London), and was designed to identify areas of weakness in topics considered prerequisite to various post-secondary programs. From this point of view, the test can be treated as being criterion-referenced. In fact, the intent of the test was that students failing to meet a specified level of performance would be referred to a remedial program. Our use of the test, however, is essentially normative. Comparisons have been made of students in this province with those at Fanshawe College. The latter group is judged to be reasonably representative of Ontario Grade 12 graduates entering community colleges in that province.

The relevant comparisons are given in Figure 4.10. Cabot Institute scores can be compared directly to those for corresponding versions of the test at Fanshawe College. The scores for MUN and Marine Institute students are for a single form of the test (the technology version was used at MUN because it was judged closest to what was required as prerequisite to first-year courses). Whatever the comparison, it is clear that students in this province attained scores which averaged about 10 points lower than their Ontario counterparts. In the case of the Cabot Institute, the difference was much more pronounced, reaching nearly 20 percent for the technology version.

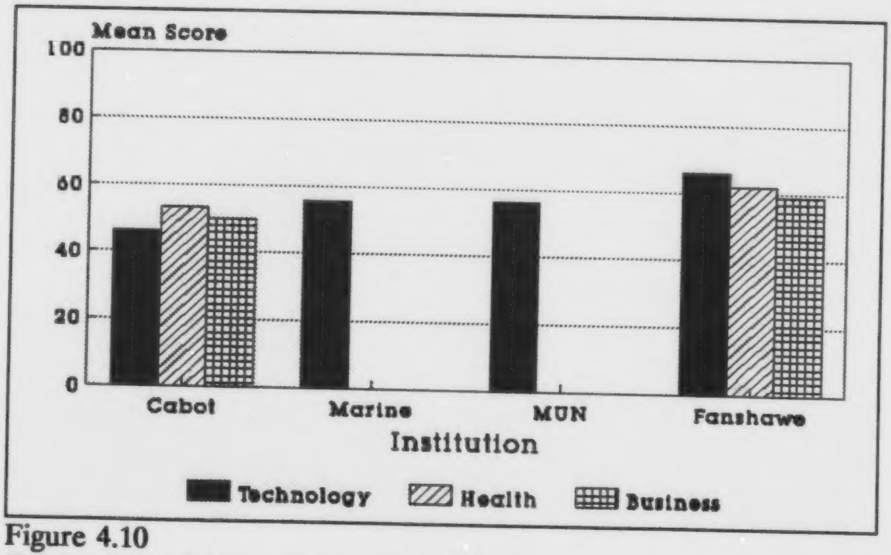

Figure 4.10
Comparison of Mean Scores, Mathematics Inventory Test

It is important to note that, because of organizational problems, only about two-thirds of the incoming MUN students actually wrote the test. (Virtually all those at the other institutions participated.) In order to determine whether those writing the test were representative of all incoming students, high school mathematics scores of students writing were compared to those of students who missed the test. On average, a difference of about four percent, favouring those writing the test, was observed. This suggests that those writing were a biased sample, and that mean scores would have been slightly lower had all students participated. (A more detailed examination of the relationships among high school and other test scores is presented in the next chapter).

Grade 7 & 8 Science

One of the issues in comparing test results across jurisdictions is whether tests are of equal validity in the settings being compared. It has frequently been argued, for example, that tests such as the CTBS may have certain biases when used in the Newfoundland setting because of differences in language usage, student experiences and so on. Similarly, bias may occur because tests have not been specifically keyed to the curriculum used in a particular jurisdiction.

One way to shed light on possible test bias is through comparative studies using tests developed for use in particular jurisdictions. In our case, the only test which was convenient for this purpose was a science test developed for use at the end of the elementary grades. This test was specifically keyed to the elementary science program used in this province. Its initial administration was to grade 6 students in May, 1987. It was possible to make an arrangement with the Province of British Columbia to have this test administered to a sample of some 2000 students in that province in the Fall of 1988. Because of the time of year, it was decided to use grade 7 instead of grade 6 students for this purpose. To allow a more direct comparison, the test was readministered to a comparable sample of grade 7 students in Newfoundland at the same time as the British Columbia administration.

For further comparison, a test designed in British Columbia, and administered to all grade 7 students in that province in May, 1986, was also given to a sample of Grade 8 students in Newfoundland. Since it was not possible to readminister this test in British Columbia, the Newfoundland Grade 8 (beginning of year) results are compared to those for Grade 7 (end of year) students in that province.

All of these results are summarized in Figures 4.11 and 4.12. For the Grade 7 (Newfoundland) test, B.C. students performed marginally better on the process and biological science subtests, and about the same on the physical and earth science subtests. The overall total was about three percent higher for B.C. than for Newfoundland students.

The B.C. test had six subtests. Scores were about the same on four of these subtests, while B.C. students performed substantially better than their local counterparts on the remaining two (process and knowledge), and on the total score. On three of the subtests, application, critical thinking, and technology, students in both provinces performed relatively poorly. Both groups did quite well on the safety subtest, which dealt primarily with safety in laboratory settings.

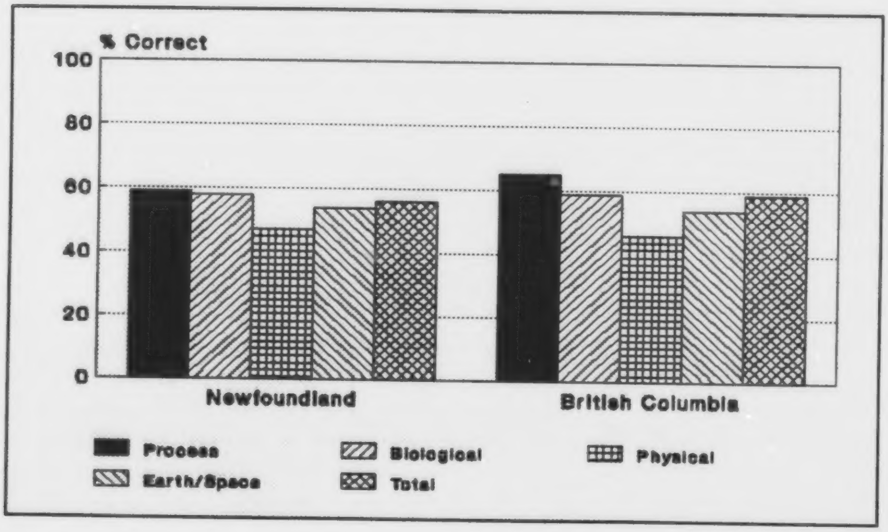

Figure 4.11
Newfoundland/British Columbia Comparisons,
Grade 7 Science

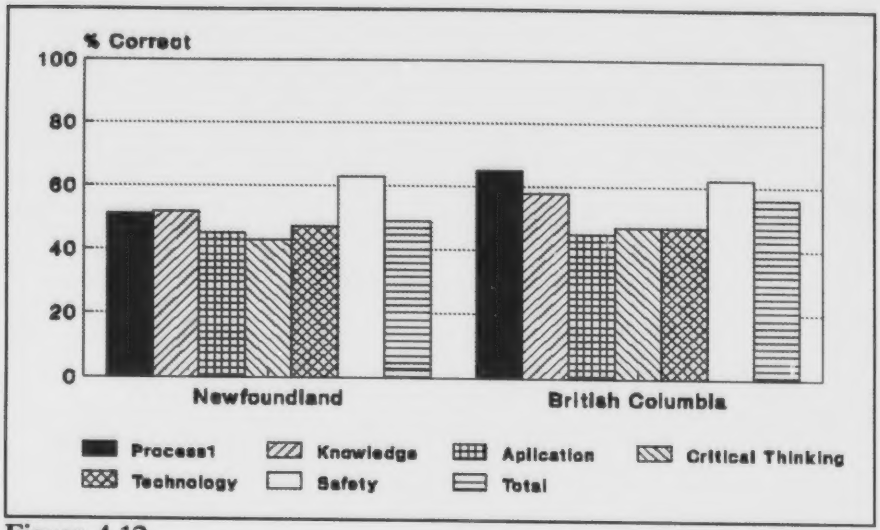

Figure 4.12
Newfoundland/British Columbia Comparisons,
Grade 8 Science

Overall, the results suggest that students in British Columbia have a better grasp of aspects of scientific process, and have superior general knowledge in science than their counterparts in this province. While the differences are not overwhelmingly large, they are statistically significant and consistent with patterns seen in various other tests. The grade 7 comparisons, in particular, would seem to rule out bias against Newfoundland students in other tests as a major source of the discrepancies in scores. Even though the differences were smaller on this test than on the B.C. test, the bias hypothesis would suggest that B.C. students would be expected to perform more poorly than Newfoundland students on such a test. (That is, bias, if it exists, would be expected to work against the British Columbia students on a test designed for use in Newfoundland.)

Factors Associated with Achievement

One of the most vexing problems in analyzing educational data has always been that of identifying the underlying causal factors which contribute to differences in achievement. The problem arises from the existence of multiple causes, the inability to obtain reliable data on certain variables, and the limitations of the analytical tools available. In education, it is also generally impossible to conduct the kind of experimental studies necessary to distinguish causal factors from those that are merely coincidental. The Task Force devoted considerable effort to an attempt to develop a causal model for science and mathematics achievement, without being any more successful than others have been in solving the underlying problems of analysis. This section presents a highly simplified picture of some of the factors associated with higher or lower achievement. In interpreting these results, it must be kept in mind that these relationships are essentially correlational, and that it has been impossible to separate the many confounding factors which may underlie some of the relationships reported. This is especially true for attitudes, since it is impossible to determine if poor attitudes lead to poor achievement or if the reverse is true.

Demographic Differences. One of the major concerns in education in this province has been the continued decline in enrolments and the consequent increase in the number of small schools. This concern is so pronounced that a special study of the problems of small schools was commissioned in 1987.[3] Much of the concern with small schools has been over staffing, funding, and access to specific programs. However, the specific issue of interest here is that of achievement levels.

A fairly detailed analysis of differences in achievement by school size, urban/rural setting and school district has been given in **Background Report #1.** The main results of this analysis may be summarized as follows:

1. Generally speaking, students in larger schools and in schools

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[3] Riggs, F., **Report of the Small Schools Study Project**. St. John's, Newfoundland: Jesperson Printing, 1987.

in urban settings (there is, of course, some overlap between these categories) perform marginally better in public examinations than their counterparts in small schools and those in rural settings. Differences range from two to four percentage points, depending on the subject.

2. This pattern is reversed for academic mathematics, essentially because students who would find themselves enroled in the advanced course if they were in larger schools have access only to the academic course in smaller schools.

3. The pattern observed for the public examinations also holds for the CTBS results.

4. Differences among school districts are far larger than those for the urban/rural or school size breakdowns. It is not unusual to find 25 or more percentage points separating the lowest from the highest performing districts. This suggests that characteristics of a school district, beyond the rural/urban distinction, have a major influence on achievement.

Gender Differences. There is a large body of research which indicates that girls participate in smaller numbers and have and lower achievement than boys in mathematics and science. In fact, the recent international science study[4] showed almost universally lower achievement for girls. Most of the data for this province show a rather different picture. Again, only a brief summary is presented here of a more detailed analysis which appears in the background report.

1. On the public examinations, differences favouring girls were found for both advanced and academic mathematics. These differences were in the same direction for both public and school marks, but were statistically significant only for the

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[4] International Association for the Evaluation of Educational Achievement. **Science Education in Seventeen Countries: A Preliminary Report.** London: Pergamon Press, 1988.

public examinations.

2. Differences were in the opposite direction, favouring boys, for the business mathematics course.

3. In general, only very small and inconsistent differences were found for the science courses. The main exception was school marks for physics, which favoured girls by about four percentage points.

4. Differences in performance in first year university courses were generally small and in no consistent direction.

5. Differences in CTBS scores tend to favour girls on all subtests in grades 4, 6, and 8. The pattern is reversed in grade 12, with boys outperforming girls on all but one subtest. The difference is most pronounced in mathematics, where more than 10 percentile ranks separate boys and girls.

6. For the grade 6 science test, no significant differences between girls and boys were found.

The overall pattern of gender differences in this province is one which seems to favour girls. The only notable exception to this is the performance of grade 12 students on the CTBS. This suggests the possibility that the pattern of bias against girls found in most studies is somehow a function of the structure of standardized tests or of the conditions of their administration. Where the results count most, particularly in high school or university performance, the usual bias seems to disappear.

Home and Community Conditions. Data on the home and community circumstances of students were obtained from the high school and post-secondary surveys administered by the Task Force. These data were then matched with both public examination and university achievement at the level of the individual student. (The match could not be performed for other post-secondary students because the required individual achievement data were not available in appropriate form.) The pattern of relationships emerging from an analysis of the matched files was quite complex. Among the more interesting relationships were the following:

1. Factors such as areas of the province, school size, and community size all tended to influence achievement. Generally, students from larger communities, particularly those on the Avalon Peninsula, tended to do better than others. The school size relationships confirmed those reported earlier, with students from larger schools tending to do better than those from smaller schools.

2. The educational and occupational level of adults in the home were significant indicators of higher achievement, as was the availability of home help with mathematics and science studies, a factor likely related to the first.

Student Work Habits, Choices, and Attitudes. The survey instruments included a large number of items dealing with student program decisions, work habits, and attitudes towards science and mathematics. Full summaries of responses to such items are found in the appropriate background reports. Certain items were selected for their possible association with achievement, and matched with the appropriate achievement data. A number of important relationships were found.

1. Time spent on homework and study was significantly associated with mathematics but not with science achievement.

2. Time missed from school or from classes was associated with lower achievement levels.

3. Students who showed persistence, and indicated that they study hard when subjects are found difficult tended to have higher achievement.

4. Negative attitudes, such as the view that mathematics is difficult, a fear of failure, and the feeling that mathematics and science are not important for career plans are all associated with lower achievement.

5. Students taking a full course load at university tend to do better than those taking part loads.

6. Students who intend to major in science areas tend to do better than those who plan other majors.

7. Finally, those taking advanced mathematics in high school tended to do better in Mathematics 1080 than those who took academic mathematics. No comparisons could be made for the other university mathematics courses because students in other courses almost exclusively came from a specific high school course (Advanced Mathematics for those in Mathematics 1000 and Academic Mathematics for those in 1050).

General Conclusions

The data presented in this chapter, and in the associated background reports, seem to warrant several broad conclusions about the state of science and mathematics achievement in this province. These conclusions are reiterated here because they address directly the first part of the terms of reference of the Task Force, and because they form the basis for the remainder of the analysis.

1. In comparison with Canadian and international standards, achievement in mathematics and science in this province is consistently low. This is not an artifact of particular measures, but is a pervasive feature of the system.

2. Public examination results have shown remarkable stability over the past decade. However, there is reason to believe that this results from a system designed to achieve exactly this effect. In particular, public examination results are subjected to a normative interpretation which ensures that the results in a given year are no worse than those in previous years.

3. Success rates in the high school advanced mathematics

course are significantly higher than those for academic mathematics, suggesting that the advanced course is undersubscribed.

4. There has been a real and significant decline in achievement levels of first year mathematics students at Memorial University over the past several years. This decline does not appear in other subject areas.

5. A decline of lesser magnitude appears for both mathematics and science courses at the Cabot Institute. However, mathematics results at the Marine Institute have remained relatively stable.

6. Overall success rates in first year university mathematics have always been significantly lower than those in other subject areas. This situation has worsened in recent years.

7. Gender differences in mathematics and science achievement are generally quite small. Contrary to what is found in most studies, the differences which exist tend to favour females more often than males.

8. Students from larger schools and schools in urban areas tend to achieve at higher levels than those from smaller and rural schools. However, these differences are quite small compared to the differences which exist among school districts. This suggests that the emphasis on school size as a factor in achievement may be exaggerated, and that the district would be a more strategic focal point for efforts at improving achievement.

9. A number of variables associated with the home environment and with student attitudes and work habits are significantly associated with achievement. In particular, students who work harder, who miss less school, and who have help at home tend to do better than others.

CHAPTER 5

ENROLMENTS AND PARTICIPATION RATES

Although the general framework of this study is one which attempts to shift the primary emphasis in schooling towards higher levels of achievement, it is not intended that this be done by creating a system which excludes large numbers of young people from the process. It is important to continue to improve overall school retention rates as well as participation in science and mathematics programs in high schools. Moreover, it is necessary to bring about substantial improvements in participation rates at the post-secondary level.

This chapter presents the basic data on participation in school and post-secondary programs. Overall enrolment trends are examined, as well as participation rates for specific programs and courses in the areas of interest for this study. Differences in participation rates by gender and by type of school setting are also examined. All of the data used in this chapter came from Department of Education files and the registrars' offices of the various institutions. Only a brief summary of the total data base is given here. A separate research report (**Background Report #3**) conveys a much more detailed picture. Most of the tables and graphs presented here are condensed versions of those appearing in that report.

Enrolment and Participation Trends

Falling birth rates, and the consequent declines in school enrolments have been a dominant feature of the education system for many years. As long as a decade ago, the Government of Newfoundland and Labrador found it necessary to commission a full review of the education system in light of this phenomenon.[1] The report of that study documented a decline from almost 163,000 students in the peak year 1968 to about 153,000 a decade later. At that time, it was projected that enrolment would further decline to around 121,000 in 1988 before levelling off during the 1990s.

As it happens, these projections have been very close to the mark. As Figure 5.1 shows, enrolments over the past decade have continued to decline. A small increase was registered in 1983 with the first students entering grade 12. The decline has also been reduced somewhat by improvements in the overall retention rate of schools, as indicated in the next section. The grade level enrolments shown in Figure 5.2 are sufficient to indicate that we have not yet seen the end of this trend, since there are continuing decreases in enrolments in the early school years. In fact, the most recent projections prepared by the Department of Education, show enrolment continuing to fall for the next several years.[2]

Figure 5.3 shows that enrolments Memorial University have not followed the trend indicated by school enrolments. Despite the general stability in the pool of available students graduating from high school, Memorial University has grown substantially since the early 1980s. The trend towards choosing university education is also apparent from surveys of career aspirations of students. It is clear that university is the preferred post-secondary route for ever larger proportions of students.

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[1] Task Force on Education. **Improving the Quality of Education: Challenge and Opportunity.** St. John's, Queen's Printer, 1979.

[2] Department of Education, **Trends in Education. Demographic Projections, Part I.** St. John's: Queen's Printer, July, 1986.

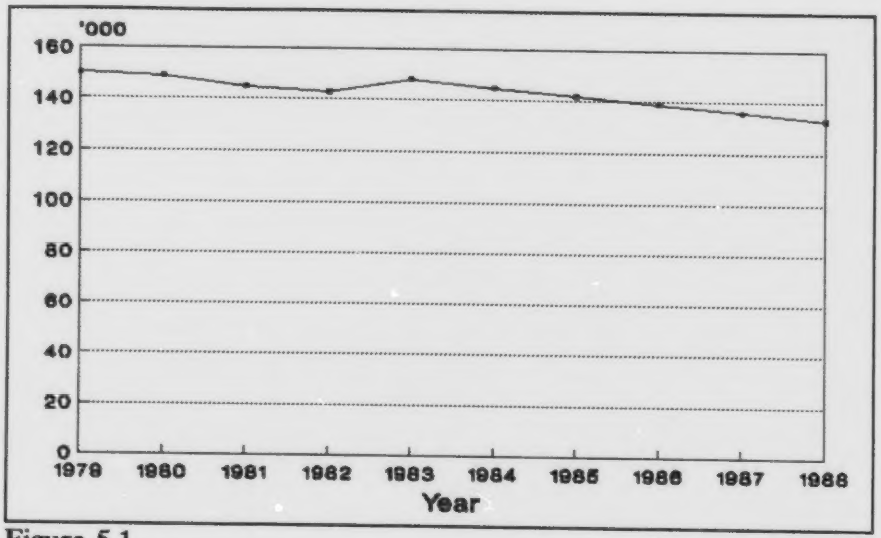

Figure 5.1
Total School Enrolments, 1979-1988

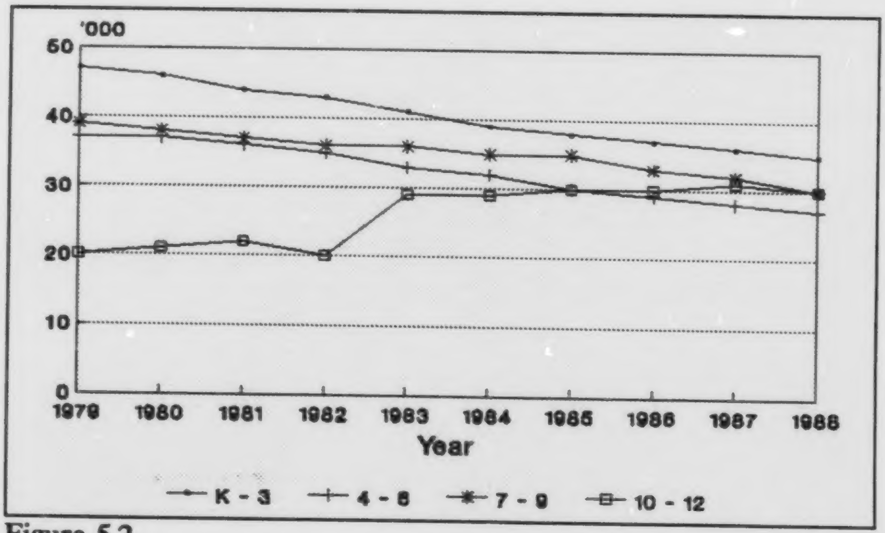

Figure 5.2
Enrolments by School Level, 1979-1988

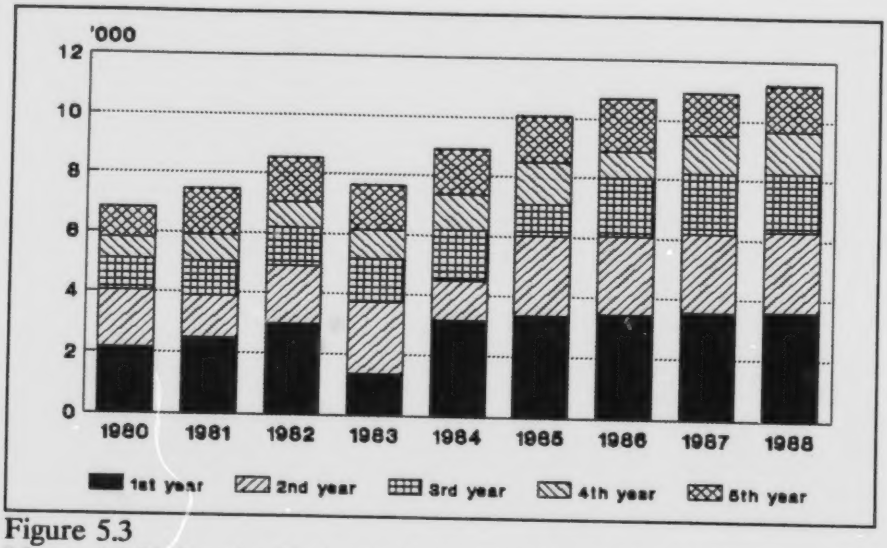

Figure 5.3
Memorial University Undergraduate Enrolments by Year, 1980-1988

As for the other institutions, the numbers have remained fairly stable, largely because these are determined by quotas and are independent of the size of the high school graduating group. Each year a combined total of approximately 1000 students is accepted into post-secondary programs at the Cabot, Marine, and Fisher Institutes. However, fewer than half of these students come directly from high school. The reminder are individuals who have been out of school for one or more years. Unfortunately, no clear information is available on what these students had been doing in the meantime.

As indicated earlier in this report, the 1980s might be characterized as a decade of concern for increasing the retention power of the school system. One common index of retention is the number of grade 8 students who graduate from high school four years later. The trend in this index is shown in Figure 5.4. By this measure, it is clear that there has been a substantial improvement in recent years. Other measures, such as proportion of the age group in school or the dropout rate in a single year, though different in detail, show a similar

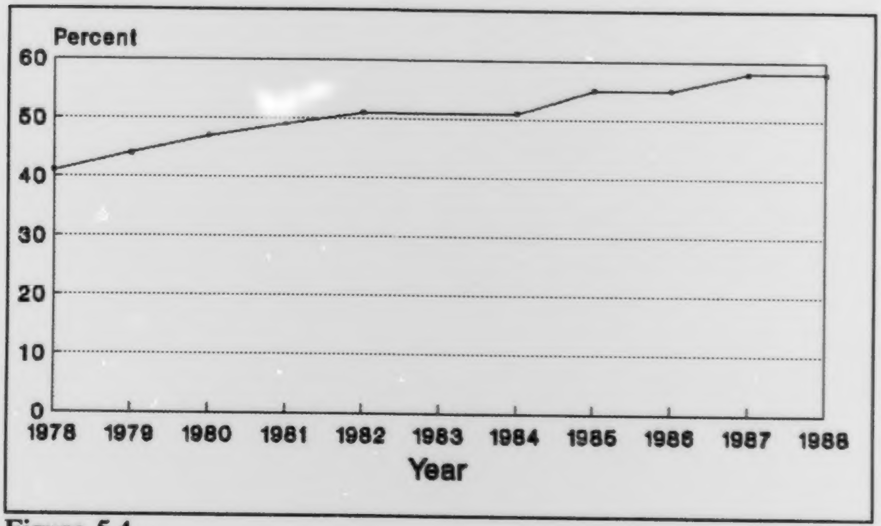

Figure 5.4
High School Graduates as a Percentage of Grade 8 Enrolment

trend. This province is now retaining as many students through to high school graduation as most other provinces. Despite this trend, there is little room for complacency, as we are still some considerable distance from the goal of achieving full participation up to the end of high school education.

It is a much more difficult task to obtain a picture of retention at the post-secondary level. Although considerable concern was expressed about losses from post-secondary programs, accurate summary statistics were difficult to locate. At the university level, in particular, students often complete their programs at widely different rates. The large number of part-time students also complicates the picture. Added to this, the drop in first year enrolment in 1983, when there were no high school graduates, is still working its way through the system.

A rough idea of the pattern of retention can be obtained by comparing the trend in the number of degrees and diplomas awarded

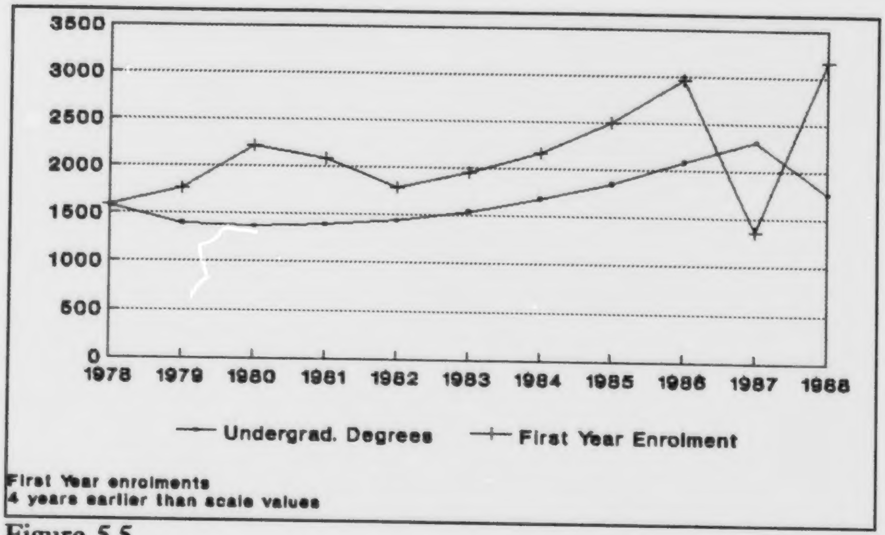

Figure 5.5
Memorial University Undergraduate Degrees Compared to First Year Enrolments, 1981-1988

with that in the number of first year students admitted. These figures for Memorial University are presented in Figure 5.5. As can be seen, the number of degrees awarded has been increasing at an accelerating pace, except for the past year, where the decline can be directly attributed to the reduced intake in 1983, when there were no high school graduates. The number of degrees awarded is also reasonably close to the number of students admitted four years earlier, suggesting that overall attrition in university programs is not especially high. It must be kept in mind, however, that many degrees are awarded to part-time students and others who have taken more (sometimes less) than the normal four years to complete a degree. Nevertheless, these numbers would be expected to balance out to the extent that real attrition rates should be close to those indicated by the gap between the two lines shown in the graph.

The picture at the Cabot and Marine Institutes is somewhat more straightforward, because students normally progress through programs as a group, and because overall admissions to these institutions have been quite stable in recent years. This allows a direct comparison of numbers admitted and numbers graduating. The appropriate comparisons, for selected programs, are shown in Figures 5.6 and 5.7. In general, attrition is extremely high, especially at the Marine Institute. Overall, fewer than half of those entering the Cabot Institute and only about one-fourth of those entering the Marine Institute can be expected to graduate. Attrition on this scale obviously wastes substantial resources within these institutes, especially when we consider that entrance quotas are based on the assumption that all students admitted must be assured places if they choose to continue. The result of this is underutilization of resources at the later stages of the programs in these institutes.

Participation in High School Courses

Our main concern is with what is happening in mathematics and science. It is particularly useful to know whether the trends in these areas are different from the general patterns of enrolment and retention.

Figure 5.8 gives the trends in enrolment in the final year high school mathematics courses over the past decade. The overall picture is one of little change in total enrolments in mathematics, as might be expected since almost all students take mathematics each year. As for the different courses, academic mathematics enjoyed some increase until the past year, when there seems to have been a slight shift in favour of the advanced course. None of these changes, however, are particularly significant.

Enrolment trends in final year science courses are presented in Figure 5.9. Here the overall picture is clearly one of increased participation. The increased enrolments in all subjects, in the face of stable total enrolments in the system, indicates that individual students are opting to take more science courses than before. It is interesting that this has occurred following the revision of the high school

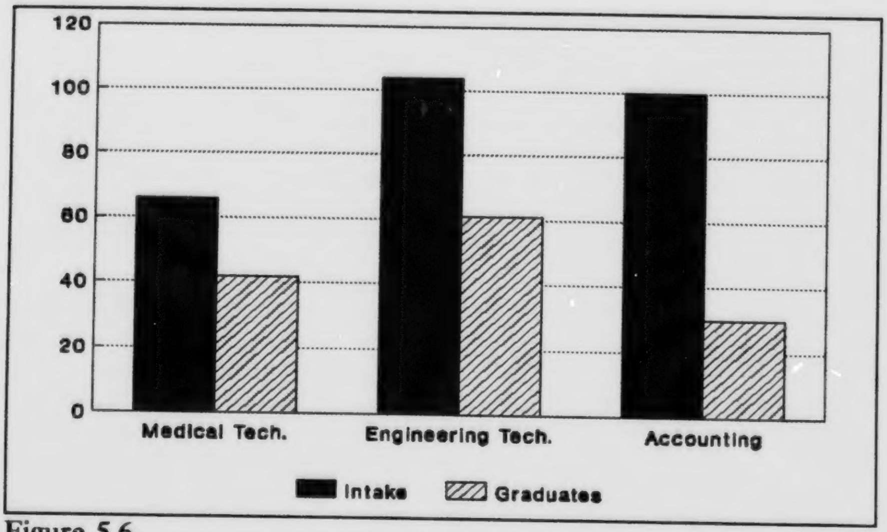

Figure 5.6
Cabot Institute Graduates Compared to First Year Admissions, 3 Year Average

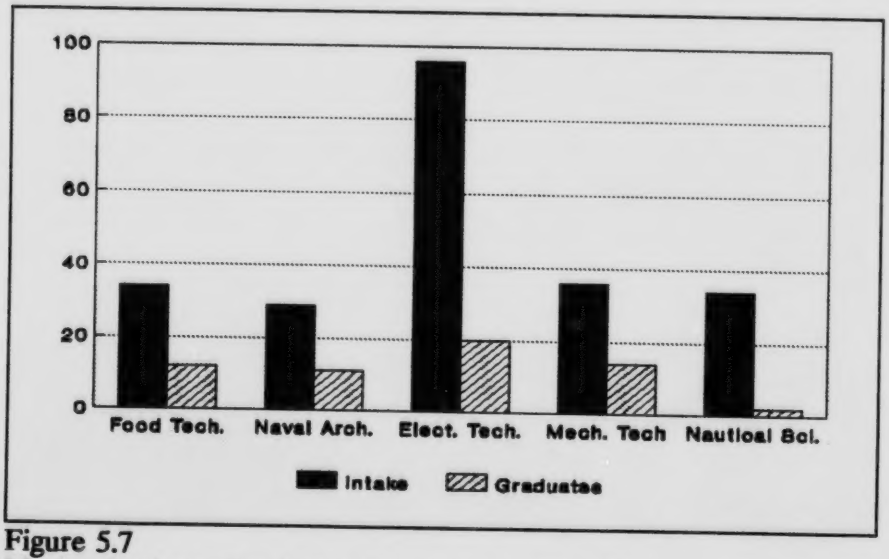

Figure 5.7
Marine Institute Graduates Compared to First Year Admissions, 3 Year Average

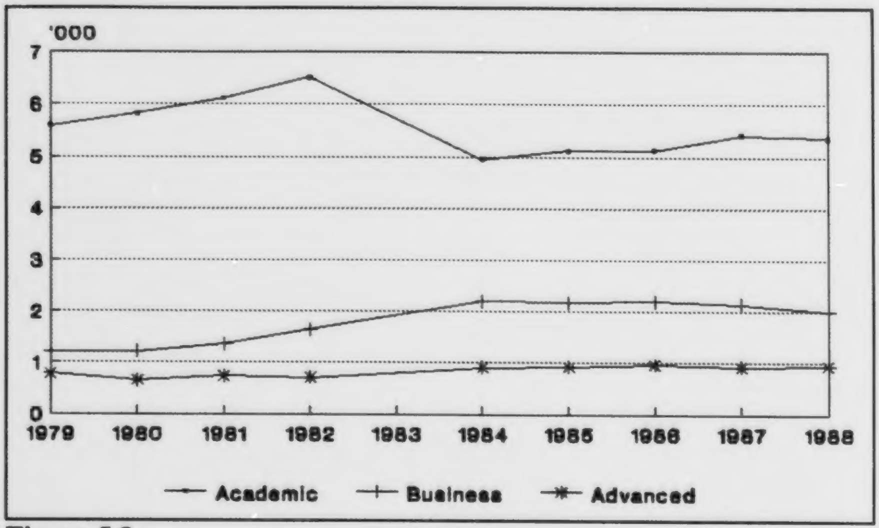

Figure 5.8
Public Examinations Candidates, Mathematics Courses, 1979-1988

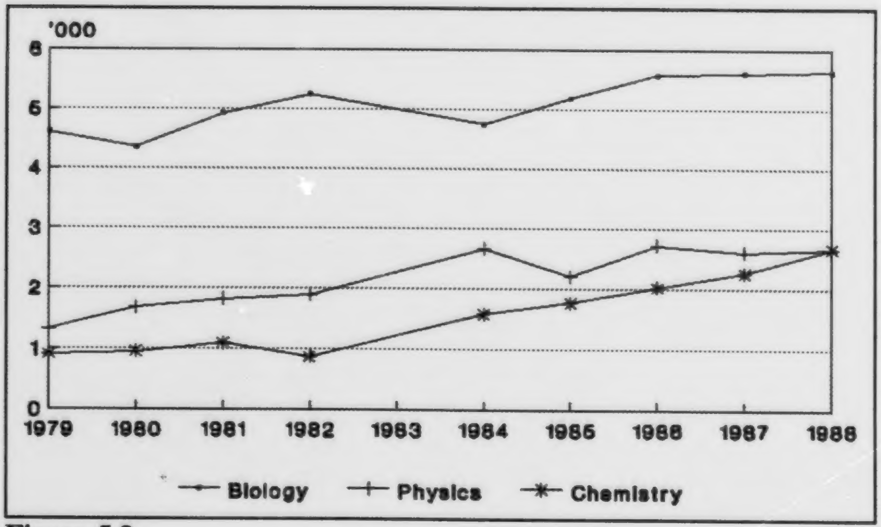

Figure 5.9
Public Examinations Candidates, Science Courses, 1979-1988

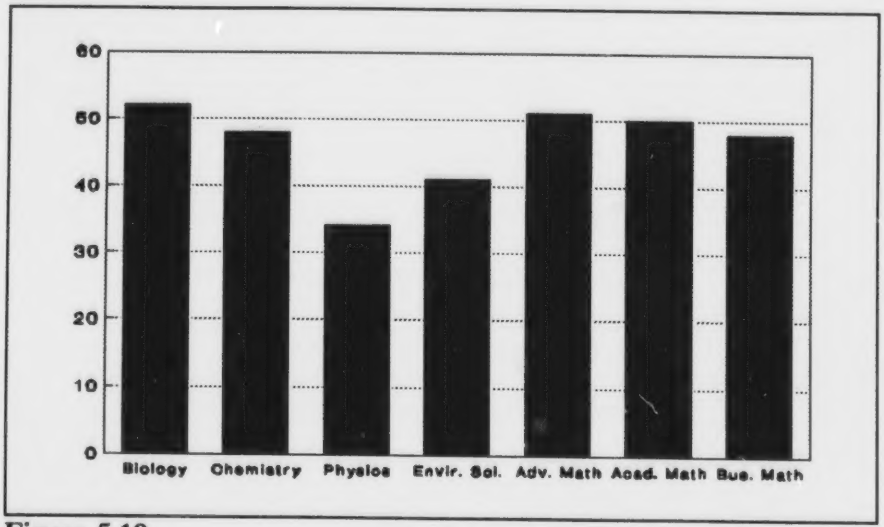

Figure 5.10
Percentage of Females in Final Year High School Mathematics and Science Courses, 1988

program, which effectively allows students to graduate with fewer science courses than in the previous program.

In general, therefore, we can say that the tendency has been towards substantial improvements in participation in science throughout, with more marginal favourable shifts in mathematics. Despite these gains, however, enrolments in physics and chemistry remain substantially below those in biology. Growth in advanced mathematics has also been extremely slow, considering the high success rates in this course and its value for post-secondary performance.

Data presented in the previous chapter indicated that there are few achievement differences between males and females in high school programs. It is important also, of course, to ask whether there are gender differences in participation rates. Figure 5.10 shows the proportion of girls in the various final year mathematics and science courses in 1987 (patterns for other years are about the same). As can be seen, there is a substantial imbalance in enrolment favouring males in physics and environmental science. However, all other courses show an almost even division between males and females. It is especially interesting to note that, contrary to some expectations, there is no tendency for girls to opt for academic rather than advanced mathematics. While, overall, there seems to be little cause for concern about low participation of girls at the high school level, the figure for physics does foreshadow a pattern which appears much more strongly at the post-secondary level.

A second area of concern which parallels that for achievement is the presumed lack of opportunities for students in small schools. Again, looking specifically at final year mathematics and science courses, Figures 5.11 and 5.12 give the proportions of schools of different sizes offering these courses in 1988. These figures show that academic mathematics is the only subject which does not show school size effects. For all other courses, the size of school is a strong determinant of whether the course is available. For the smallest schools (those with fewer than 25 grade 12 students), opportunities to take advanced mathematics, chemistry, and physics, in particular, are severely limited. Even in the case of medium sized schools (those having between 25 and 99 grade 12 students), only about half offer advanced mathematics or chemistry.

Participation in University Courses

Trends in total Fall Semester enrolments in first year mathematics and science courses at Memorial University are shown in Figure 5.13. For comparison purposes, total first year enrolments have also been indicated. Overall, the data show a trend towards decline in all subjects over the past three or four years, despite the continued increase in overall enrolment. The decline is especially evident in mathematics. While part of this decline can be attributed to shifts in patterns of course offerings, trade-offs between Fall and Winter Semesters, and the like, more detailed breakdowns by course given in **Background Report #3** indicate that the decline is real, and that mathematics and science are attracting a substantially smaller proportion of first year students than in earlier years. The decline in mathematics is particularly noteworthy because it coincides with the decline in success rates and, more important, because it means that

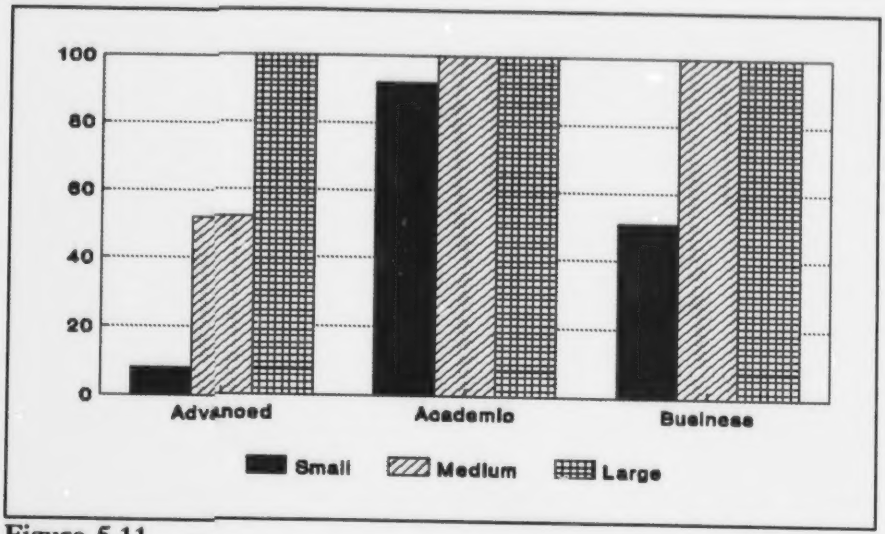

Figure 5.11
Percentage of Schools Offering Final Year Mathematics Courses by Size

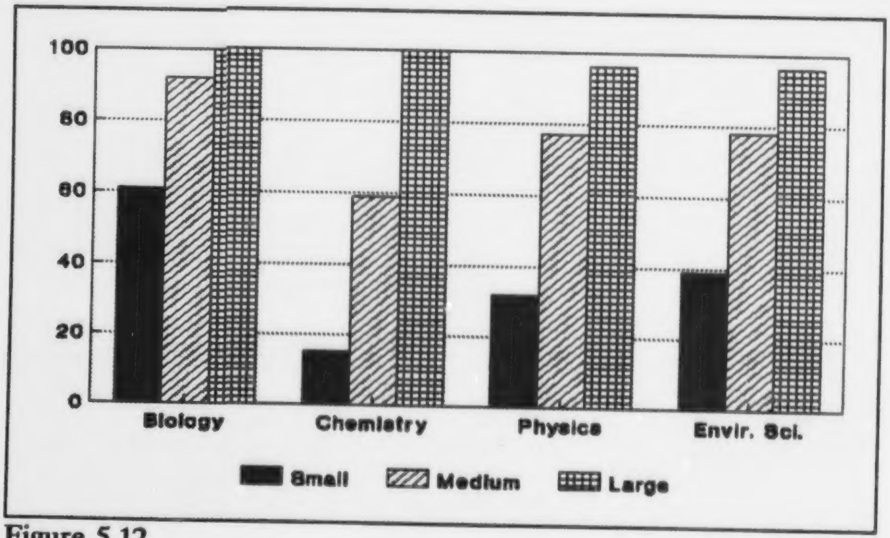

Figure 5.12
Percentage of Schools Offering Final Year Science Courses by Size

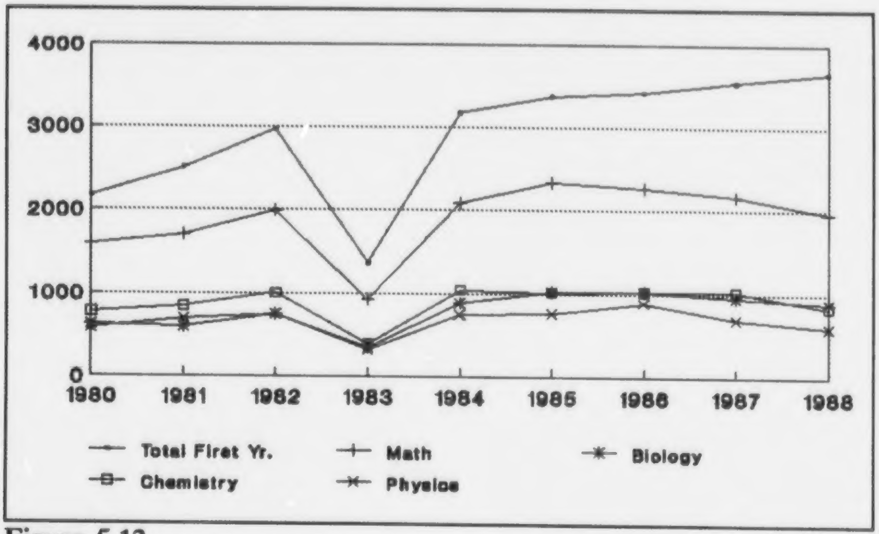

Figure 5.13
Memorial University Fall Semester Enrolments,
Selected First Year Courses, 1980-1988

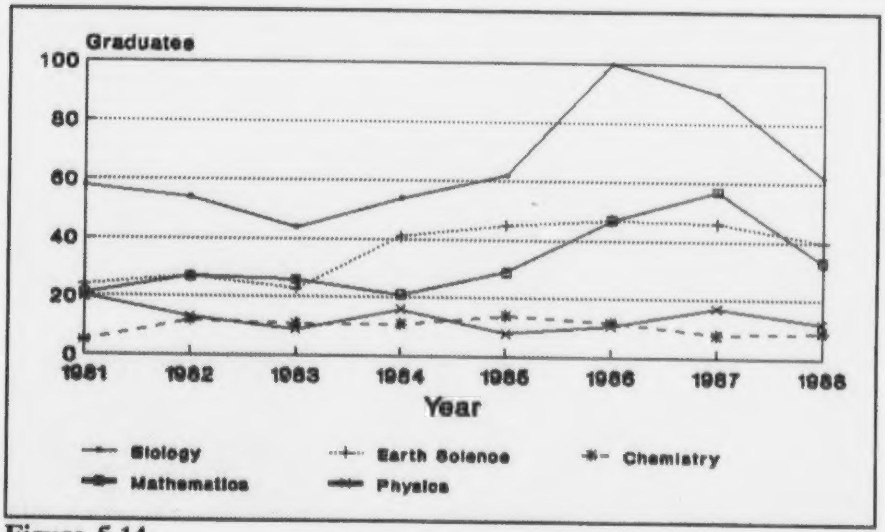

Figure 5.14
Memorial University Graduates, Selected Science Disciplines,
1981-1988

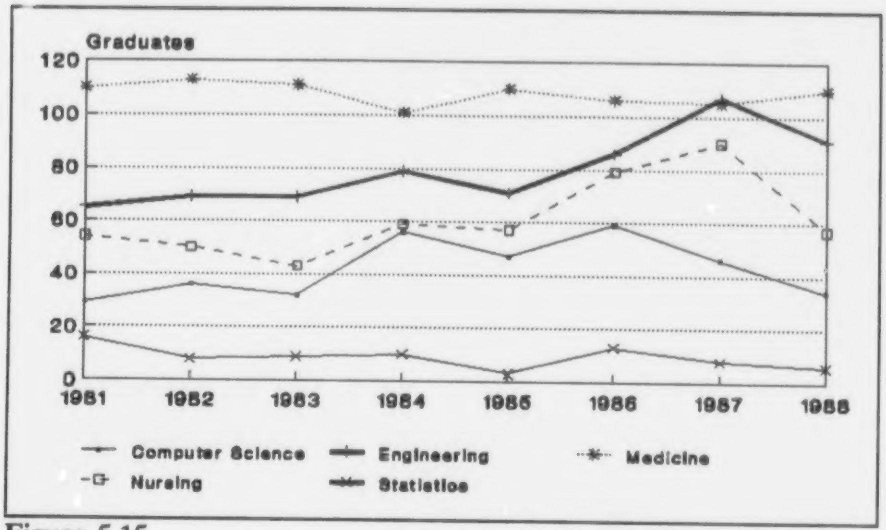

Figure 5.15
Memorial University Applied Science and Professional Graduates, 1981-1988

increasing numbers of students are narrowing their options for further study, since few degree programs are open to students who have not completed first year mathematics.

Of more concern than the numbers at the beginning level is the number of graduates in various science-based fields. Trends in numbers graduating in selected science disciplines appear in Figure 5.14. Figure 5.15 gives similar data for professional fields which require substantial science backgrounds. The first striking feature of these figures is how small the number of graduates actually is, compared to the number of students taking first year courses, and compared to the total number of graduates from the university. Science and mathematics are obviously not particularly popular fields.

It is important to note that at least part of the recent decline in graduates can be attributed to the introduction of grade 12 in 1983, which resulted in a large drop in first year enrolment that year. This point has already been noted in examining the total numbers graduating. Those who would have entered first year undergraduate programs would normally have been graduating in 1987. Given that programs are of different lengths, and that students do not always progress at a normal pace, it is not surprising that there would be a depression in the number of graduates for several years following the expected year. At the same time, the decline in overall numbers taking first year courses suggests the possibility that a sustained decline in mathematics and science is in the making. At present, there is no way to predict the extent of such a decline.

Although there was little evidence of inequality in participation of women in high school science courses, the same cannot be said for post-secondary programs. Percentages of females in various science based programs at Memorial University in 1988 are shown in Figure 5.16. Similar Figures for the Cabot Institute are shown in Figure 5.17. Here is obvious that the traditional gender split between the physical and life science remains a strong factor. Nursing remains an almost entirely female field. The biological sciences, including medicine, now have a reasonably equal balance of males and females. At the opposite extreme are mathematics, physics, computer science and, especially, engineering, all of which are strongly male dominated. It should be noted that although these figures are for 1988, there have been few systematic changes in the proportions in recent years. Except for medicine, women have made few inroads into male dominated fields, nor have men been attracted to nursing. There is clearly a long way to go to achieve equality in career choice between the sexes.

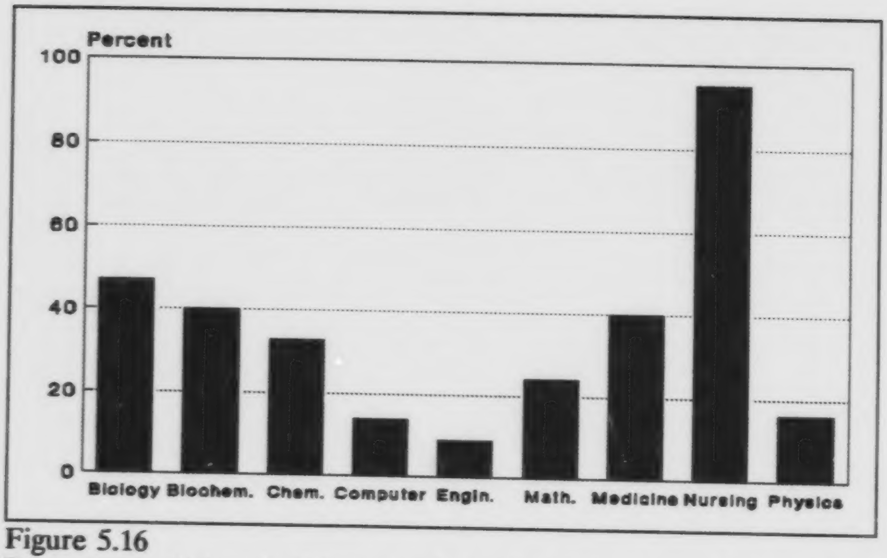

Figure 5.16
Percentage of Female Science and Applied Science Graduates by Discipline, 1988

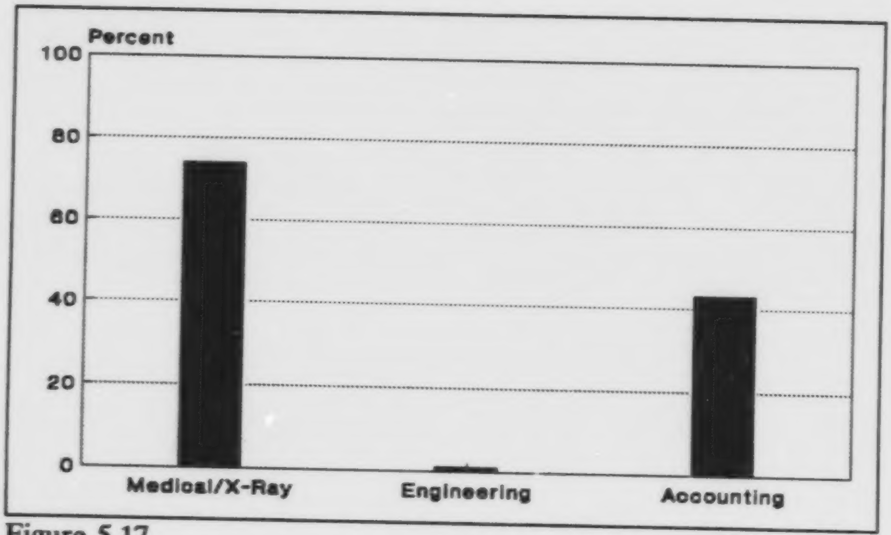

Figure 5.17
Percentage of Female Graduates in Selected Cabot Institute Programs, 3 Year Average

CHAPTER 6

PUBLIC AND PROFESSIONAL PERCEPTIONS AND OPINIONS

A large number of individuals, groups, and organizations have a stake in mathematics and science education. The views of stakeholders are important for a number of obvious reasons. First, there are limits to what can be learned by looking only at "hard" data. Test scores and enrolment patterns can tell us much about the problems but little about the solutions. On the other hand, stakeholders are likely to have many insights into the solutions to various problems. More important, stakeholders are the obvious source of political influence, and can help ensure that possible solutions are acted upon. Finally, particular stakeholders, namely those responsible for the day to day operation of the system, will ultimately have the task of implementing the recommendations.

Following common practice in public inquiries of this sort, the Task Force sought to obtain as wide a sampling as possible of the views of those concerned with the problem at hand. Data were gathered from a variety of sources. A call for submissions yielded nearly 100 briefs, letters, and calls from parents, teachers, and other individuals, as well as briefs from most of the major organizations concerned. In order to ensure that public input was not confined to those individuals taking the trouble to prepare a submission, a public opinion poll was commissioned, in collaboration with a parallel Task Force on Educational Finance. Sample surveys were also conducted with elementary and high school teachers, post-secondary instructors, high school students, and first-year students at the post-secondary institutions.

The largest single activity for the Task Force staff consisted of interviews with representatives from most of the major stakeholder groups, including school boards, the Department of Education, Memorial University, the Cabot and Marine Institutes, the Newfoundland Teachers' Association, and a variety of others. Focus group discussions were held with a sample of first-year university students. Finally, a one day consultative workshop was conducted toward the end of the study, in which invited individuals representing the major stakeholders were asked to react to some of the tentative findings and proposals of the Task Force.

The views presented through all of these sources were so diverse that they almost defy summary. Nevertheless, it was possible to identify certain common themes, and some consensus of opinion at least within specific groups. This chapter represents an attempt to identify the main issues addressed by the various sources. No effort is made to present a comprehensive summary, however, as this would occupy far too much space. Readers who wish to look more closely at the views presented are referred to the various background reports, as listed in Appendix A. The chapter is organized by source of information rather than by theme because this seemed to be the simplest way to convey a sense of unity of opinion. Looking across the groups, and sometimes even within them, however, it is important to point out that many conflicting opinions exist. In formulating its own judgements, the Task Force took careful account of the views expressed, but did not feel bound by any particular view, especially where conflicts did exist or where views were contrary to the evidence available from more direct sources.

Parent and Public Submissions

A total of 21 submissions were received from individuals who identified themselves as parents, or who spoke of their experiences with their own children in the school system. A further 9 submissions came from community groups, individual citizens, or others with no direct professional ties to education. Most of these submissions took the form of letters addressing one or two specific points. A few were much more comprehensive, addressing broad issues such as the aims of education or the importance of science.

The primary theme running through the parent submissions was that of a sense of helplessness in the face of their children's problems, especially in learning mathematics. Closely tied to this theme was a perception of the inability of the school system to help them overcome these problems. Most of the complaints (and the letters were distinctly ones of complaint) concerned specific individual needs that were not being met; ranging from students being unable to get individual help, to the lack of challenge for exceptionally capable students. Most parents reported that they themselves were unable to deal with mathematics. It is interesting to note that this was sometimes attributed to the difference between the "old" and the "new" mathematics. Parents clearly felt that it is the school's responsibility to deal with any specific problems their children might be having.

A number of parents felt that the high school program is not rigorous enough. Teachers were perceived as having low expectations and of being unable to motivate students to excel. Parents almost universally felt that mathematics and science are extremely important, and that it is the function of the school to prepare students for post-secondary studies in these areas.

Specific suggestions for change included the following:

1. Schools should provide better information on programs, and especially on the limitations of basic and academic mathematics.

2. Teachers should be more sensitive to individual student needs, and be prepared to give extra help when needed.

3. There should be increased emphasis on problem-solving and on basic skills. (It is not clear if these were viewed as conflicting or complementary aims.)

4. Students should be challenged more in school.

5. Classes should be smaller.

Other members of the public tended to take a much broader view of things. Many concurred with the opinion that school programs should be more rigorous and better prepare students for post-secondary studies. Several concerns were expressed about the quality of teaching and of teacher training, particularly about the qualifications of mathematics and science teachers. Class size and time were also mentioned as problem areas. A few respondents argued that the denominational system is at the root of many of our problems, because of the perceived duplication and waste inherent in the system.

Teachers and Teacher Groups

Submissions were received from a number of individual teachers, as well as from high school staff groups, school administrators, the Newfoundland Teachers' Association Special Interest Councils in science and mathematics, and the NTA parent body. As might be expected, these submissions covered a wide variety of topics. the main points can be summarized under the headings of time, curriculum, teacher education, teaching conditions, and, finally, perceptions of the quality of post-secondary instruction.

There was an almost universal call from teachers for more time to be allocated to mathematics. Interestingly, a similar point was not widely made about science, suggesting that teachers do not feel the same constraints here as for mathematics. Some argued that the high school courses should be given three credits, with a corresponding 50% increase in time allocations. In this connection, it was noted that there had been a decrease in time allocations to mathematics upon introduction of the revised high school program. Concern was expressed that a similar reduction might occur if current plans for revising the intermediate program were carried out.

Submissions called for a review of mathematics and science courses, with a view to identifying core content, clarifying the scope and sequence, and improving the linkage with post-secondary programs. Mention was also made of the need for technology education and for an emphasis on problem solving in mathematics. Several submissions referred to the poor state of computer education, and argued for an upgrading of the current computer studies course and improved computing facilities. Finally, there were calls for increasing the number of mathematics and science credits required for graduation, for increasing the number of optional courses available, and for including introductory calculus in the mathematics program.

Improving the state of preservice and inservice teacher education was a theme in several submissions. Calls were made for Memorial University to increase the mathematics and science requirements for primary, elementary, and intermediate teachers. As for continuing teacher education, the main emphasis was on broadening the range of opportunities available for teachers to participate in professional development, to include more summer institutes and courses within school districts. The point was also made that any new program introductions should be accompanied by more adequate provisions to familiarize teachers with these programs.

A number of specific aspects of the working conditions of teachers were addressed. As might be expected, these included calls for decreased class sizes, improved facilities, decreased course loads, laboratory assistants, and similar improvements. Space and materials for laboratory work in science was seen as a particular problem, as was time to prepare for laboratory activities.

The most striking aspect of the submissions from teachers was the prevalence of the view that most of the problems of post-secondary performance lie in the quality of teaching at that level. Arguments ranged from instructors' ability to communicate, to class size, to the preoccupation of university professors with research at the expense of teaching. Several briefs referred to a need for professional training in teaching for university instructors. Others expressed the view that Memorial University is too large and impersonal, and that professors are at best indifferent to the needs of first-year students. As we shall see, this almost hostile view on the part of high school teachers is reciprocated by their post-secondary counterparts, who have developed their own, rather different,repertoire of perceived faults with high school teaching.

One point raised in interviews with a number of teachers was the perception that many students seem indifferent about schooling, and are not prepared to do the work required to perform well. Some teachers argued that the revised high school program encouraged this tendency, by allowing students to spread the load over more time or, more often, to take the most demanding courses in the first two years, leaving the last year as an easy year. Some went so far as to argue that the poor work habits developed in Grade 12 are a source of the difficulties students encounter at the post-secondary level.

Establishment Groups

The organizations included in this category are those with official responsibility for educational policies and their implementation, at the elementary and secondary levels. Specifically, these include the Department of Education, the Denominational Education Councils, and the school boards. For these groups, the points made in submissions were elaborated or reiterated in interviews. References in this section are to both sources.

Although these are the official agencies, considerable divergence of opinion was evident. In particular, other agencies tended to be critical of a number of aspects of Department of Education policies and activities. This is not unusual, of course, and seems to reflect a general perception that the Department sometimes initiates policies without providing adequate support to those who must carry out these policies. For its part, the Department of Education took no particular pains to defend its own policies, but, instead, called for improved access to courses, improved facilities, and, in particular, changes in teacher education.

As in other cases, curriculum, time, facilities, and teacher education were the main focal points of the submissions and interviews. However, the views on these were not always the same as those of groups and individuals outside the establishment, nor was there agreement among the establishment group. Several new points may therefore be made.

School boards tended to be preoccupied with the problem of delivering courses and of offering students some variety within the high school program. Many referred to the almost impossible task they face in trying to offer a broad program in small schools, because of lack of staff and low demand. Despite these concerns, there was strong support for the general principles behind the revised high school program. Few would advocate a return to a narrow academic program, although there was a feeling among some that the revised high school program may have gone too far in aiming for breadth. As for specific courses, there was widespread dissatisfaction with the current academic mathematics course. A variety of suggestions for change were made, including a core/options approach which would allow for remediation and enrichment, division of the course into separate algebra and geometry components, and a rearrangement of the sequence so that the material most relevant to post-secondary work appeared in the final year. Opinion was divided as to whether more students should be encouraged to take advanced mathematics. Some felt that having too broad an ability range in this course could lead to a decline in its standard. Others felt that there is insufficient access, especially in small schools. There was some reference to a tendency for students to opt for academic mathematics because of a perception of risk in the advanced course.

Science courses were generally not widely criticized. There was a distinct view, however, that science is still receiving haphazard treatment at the primary and elementary levels, despite continuing efforts by district coordinators. Problems of access to chemistry and physics were often cited to illustrate the difficulties of offering adequate programs in small high schools.

There was no clear consensus of opinion on time. Some were of the view that mathematics needs more time. However, few believed that large amounts of time are being wasted. While there was agreement that the school schedule is disrupted by many events, most felt that such disruptions are usually justified, or that such activities as career days, spirit weeks, guest speakers, and the like are important parts of a school program. There was some feeling that examination time could be reduced, and there were indications that a number of districts have already taken steps in this direction. Boards defended their requirements that students take 42 credits instead of the 30 required by Departmental regulations on the grounds that this is necessary to ensure that students have a full schedule.

One of the major concerns of school boards, along with the Denominational Education Councils, was that of teacher misassignment. All agencies were concerned about under-qualifications of teachers in mathematics and science. Suggestions for improvement tended to follow those made by other groups - increasing course requirements, establishing minimum standards for specialization in these areas, and broadening access to continuing education programs for teachers. Problems of recruiting teachers for isolated communities were also identified.

As might be expected, both school boards and DECs were concerned about funding, and especially about the provision of laboratory space and equipment. Most boards complained of inadequate per-pupil grants to meet the needs for instructional materials. Some gave specific figures indicating that schools are being required to operate on only a couple of hundred dollars per year for science equipment. A second major equipment problem relates to computers. There were many complaints about delays in implementing a provincial policy on the use of computers in schools and in issuing guidelines for computer purchases. Some boards indicated that they were prepared to make substantial investments in computers, but were delaying their decision until the policy of the Department of Education was known.

One of the main thrusts of the mathematics component of the submission from the Department of Education was that the Task Force investigate all aspects of mathematics curriculum, from primary through high school. Specifically, it was asked that the aims of education be examined for their compatibility with the goals of mathematics education, that problems of learning in mathematics be examined, that a review of textbooks be carried out, and that the practice of having three mathematics streams at the senior high school level be reviewed. A detailed description of recent curriculum initiatives at the primary level was given, along with a plea to move in a similar direction in the elementary grades. In particular, it was argued that the manipulative materials required as part of mathematics teaching at these levels be supplied by the Department of Education. This was apparently motivated by a concern that government would not approve the necessary funding to allow this to be done.

In general, the science submission from the Department of Education presented an optimistic view of the state of science education, and of ongoing development in this area. Nevertheless, there was a call for improved space and facilities for laboratory work, and a concern that the time guidelines for primary and elementary science were not being followed. Following the arguments of the Science Council of Canada study, the submission also called for increased emphasis on technology, and for science courses to challenge the most able students. Finally it was suggested that the Task Force examine the feasibility of offering science courses by distance education as a way of improving accessibility for students in small schools.

Post-Secondary Submissions

Institutional submissions were received from the Cabot Institute, the Marine Institute, and the Mathematics Department at Memorial University. A total of 18 further submissions were received from individual instructors, department heads, and other officials from these institutions, as well as from the Grenfell College and the community colleges.

The overwhelming argument from those working in the post-secondary sector was that students entering their mathematics and science programs have been poorly prepared, both academically and attitudinally, to face the demands of this level of study. In the case of mathematics, the submissions exhibited a strong sense of frustration over student inability to carry out even simple operations. Example after example was given of errors in using fractions, cancelling, factoring, using the commutative and distributive properties, using negative numbers, and other basic properties and operations. Post-secondary personnel clearly expect nearly perfect proficiency in such areas. Lack of such proficiency is seen as evidence of failure in the school system.

From the post-secondary perspective, this failure stems from several sources. There is a widespread perception that, while the curriculum itself contains the required material, it is either not being taught or is being taught poorly. Many references were made in the submissions to perceived subject-matter weakness on the part of teachers, along with inappropriate assignments of teachers. There was a perception that students are allowed to advance without having mastered previous content, that students have developed poor study habits, and that students have not been given adequate counselling on course selection and on what to expect from post-secondary studies. Finally, it is possible to detect in the submissions a distinct sense of frustration that those at the post-secondary level have been excluded from decision-making about school programs.

Much of the criticism was directed specifically at the revised high school program. The program is seen as having contributed to a weakening of the academic core, and to the development of poor work habits presumably because of the leisurely pace and the existence of easy options. The academic mathematics course was the target of specific criticism, because of perceived inadequate depth of treatment. Loss of time for mathematics under the revised high school program was also seen to be contributing to the problem.

Criticisms of science programs centred around the lack of access to courses in some schools, inadequate use of laboratory activities, lack of facilities and, again, under-qualifications of teachers. Some noted a strong connection between problems in mathematics and those in science, attributing difficulties in science to lack of proper mathematical knowledge and skill.

On the specific problem of teacher qualifications, the concern was mainly about subject-matter knowledge. Contrary to the views of many within the regular school system, post-secondary personnel tend to view training in pedagogy to be secondary to that in the subject area as a requirement for good teaching. Many in the post-secondary sector believe that they should determine the appropriate levels of academic training for high school teachers. There is a belief that specific standards of academic subject competence should be established (e.g. those teaching high school science should have at least a B.Sc. degree) and that teachers without these qualifications should not be allowed to teach mathematics or science courses.

It is obvious that these views conflict in many fundamental ways with the views of those in the public school system. The idea that the post-secondary sector should control, or even strongly influence, elementary and secondary education is not shared by those responsible for education at these levels. Similarly, there is a basic contrast between the view of teachers as subject matter specialists and teachers as pedagogues. In fact, the most striking point of contrast seems to be the views of what constitutes the basic elements of teacher competence. On the one hand, post-secondary personnel believe that high school teachers are inadequately trained in the academic subjects. On the other, many high school teachers have argued that the pedagogical skills of post-secondary teachers leave much to be desired. Many in the public school system feel that the post-secondary institutions must share the responsibility for problems encountered by students. Post-secondary people, on the other hand, see the problem almost entirely in terms of inadequate prerequisite capabilities of students entering their institutions. In the extreme, they take their own expectations for granted, and assume that the job of the schools is to see that they are met.

Public Opinion Poll

While submissions are a useful means of obtaining the views of those with the most direct interest in a particular public policy issue, the sample survey has become the most common tool for soliciting opinion from a much more broadly representative cross section of the public. The public opinion poll used in this study involved telephone interviews with just over 1000 individuals, selected using standard techniques designed to yield as representative as possible a sample of all citizens in the province over 18 years of age. The sampling error for a sample of this size is approximately 3 percent at a 95 percent level of confidence. That is, the responses given by the sample to any particular item can be expected to be within plus or minus 3 percent, 95 times out of 100, of what would have been obtained had the whole population been asked the question. Such surveys thus give a highly accurate picture of what the public thinks about a particular issue. The major limitation of such surveys is that they make no distinction between those who know a great deal about the issue and those who know very little. It is thus necessary to confine the questions asked in a survey of the public to fairly general categories. Nevertheless, since in the final analysis the education system must reflect the wishes of the public, such surveys can be a useful tool in formulating educational policy.

The first part of the poll was concerned with public confidence, and with perceptions of the importance of various aspects of the system. In general, it can be said that the level of confidence in education is extremely high, more so than any other public institution or area of government responsibility used for comparison. People generally believe that the quality of education has improved since their schooldays, although there is some ambivalence about the state of discipline and student attitudes. Although education is seen by a majority as underfunded, it is also seen as less neglected than health care or social services. Within education, the most financially neglected areas are seen to be rural schools, handicapped students, remediation, and attention to basic skills.

The denominational system enjoys the support of a small majority. Support is much stronger among some denominational groups than others, although the number supporting the system is less than a majority only for members of religious groups outside the existing system and those with no religious affiliation. Support is directly related to educational level, with the lowest levels of support occurring for the most highly educated groups.

When presented with a list of possible functions of the school, most of those polled felt that all functions were very important. The highest importance was attached to teaching basic skills such as reading and mathematics. Attitudes, preparation for jobs, preparation for post-secondary education, preparation for a technological world, and preparation for citizenship were all perceived as very important by more than 80% of respondents. Much lower importance was given to moral and religious education. Even here, however, 58% indicated that this area was very important.

When the question was narrowed down to the importance of specific high school subjects, a similar pattern emerged. There is a clear hierarchy of subjects in the mind of the public, with English language and mathematics at the top, followed by the sciences. Social studies, French, and physical education occupied a slightly lower position, while religious education was the bottom of the list, having a substantially lower rating than the next lowest subject. It is important to note, however, that all subjects were seen as important by a large majority of respondents, so that the differences noted should not be over-emphasized.

Because of the importance of the issue of time to curriculum design, some questions on time were included in the poll. In general, the public believes that the length of the school year and school day are about right. If changes had to be made, more would prefer to see the day lengthened than the year. As for wasted time, a small majority is of the opinion that too much time is wasted on such things as sports, workshops, exams, and the like. In response to questions on homework, most people believe that the amount of homework is about right, with little difference in opinion being expressed by those with or without children in school.

The final area addressed was that of access and participation. Opinions in this area were unequivocal: nearly all respondents believe that almost all students should be expected to graduate from high school, and that all who want to attend post-secondary institutions should be given an opportunity to do so. Interestingly, there were distinct differences in views among those at different educational level and occupational levels. The most highly educated people, and those in the most advanced occupational categories were more likely to take a more restrictive view of access than those at lower levels.

High School Teacher Survey

This survey was administered to all teachers identified as teaching any senior high school class in mathematics or science in the current school year. Approximately 1100 teachers were determined to be in this category. Responses were received from 809 of these teachers. The survey focused on a number of areas, including teacher background, workload, classroom practices, time and materials.

As expected, mathematics and science teachers are generally highly qualified in general terms, with 70% holding grade VI or VII certificates. Despite this, many have quite minimal backgrounds in science and mathematics subjects. For example, about 25% of the biology teachers and more than 50% of the geology teachers reported having no university courses in the subject being taught. Mathematics fared considerably better, with only 6% having had no courses. About half the teachers reported having had no professional courses in science education, with some 40% giving the same report for mathematics education. The average experience of teachers is about 12 years. High school mathematics and science teachers are predominantly male (83%), however, there is some indication that this dominance is not as great among younger teachers.

Most teachers do not have highly specialized assignments, as demonstrated by the fact that more than 70% are responsible for four or more different courses. In fact, about 25% have seven or more courses to prepare. Outside of class, the main teacher activity seems to be marking student work. Teachers expressed some concern over lack of preparation time, especially for laboratory work.

The survey data tend to confirm other reports that substantial amounts of time are lost in the schools. On average, teachers reported a loss of about 25% from the normal 120 hours designated for a high school course. The major source of loss appears to be examinations, which occupy an average of 15 school days per year. Many teachers felt that too little time is available to cover the required content in academic and advanced mathematics, biology and chemistry. Most felt that the time is about right in physics and geology, as well as in the business mathematics course.

Teachers were asked various questions about the content and difficulty levels of the courses taught. In most cases, difficulty and depth of treatment in the courses were judged to be about right. The exception was academic mathematics, where about half the teachers rated the course as too difficult. This result is quite surprising in light of concerns about the shallowness of this course and its inappropriateness for post-secondary bound students. Textbooks for the courses were generally rated as good, with the exception of those in physics and chemistry, where a majority of teachers gave the books only fair to poor ratings. Materials other than textbooks, however, were rated much more poorly.

Teachers expressed substantial concern that students are graduating from high school without having mastered basic skills and concepts. Most feel that academic mathematics is not sufficient preparation for university. Nevertheless, there was a tendency to disagree that more students should take advanced mathematics. These seemingly contradictory results are explainable in light of interview data which suggest that many teachers believe that more students are entering university than can be expected to cope with the program demands at that level. More broadly, all of this reflects generally low expectations on the part of teachers.

Looking at this issue in somewhat greater depth, some items on the survey referred to teacher perceptions of student work habits and home circumstances. Teacher views in this area were dominated by the notion that students do not work terribly hard, that they waste time in school, that they cannot be expected to do much homework, and that parents are not very interested in their children's school work. Overall, the picture which emerges is that of a tendency by teachers to attribute poor performance to the characteristics of students, and not to school programs or the work of teachers themselves.

High School Student Survey

The views of senior high school students were solicited through a survey completed by just over 1300 students in Level III mathematics classes. The survey instrument contained items on students' home, community and school experiences and on their post-secondary and career plans.

As might be expected in this province, most students live under conventional family circumstances, namely, at home with both parents. Beyond this, the external circumstances of students are strongly related to the size of the community in which they live and the nature of the school they attend. Those in larger communities tend to come from homes where the parents are better educated, with more parents in the higher level occupational groups. Students from large communities spend their time at different pursuits than their rural counterparts. In particular, the latter spend more time watching television and engaged in sports, and less time at paid work than those in urban areas. Students in small communities have less positive views about their communities than those in larger centres, and are more likely to indicate that they will live elsewhere in the future.

An overwhelming 95 percent of students indicated that they planned to continue their education beyond high school. Memorial University was the most common destination mentioned, with some 40 percent of students planning to attend that institution. Specific plans are influenced by school and community size, with more students from larger centres planning to attend university, and particularly universities other than Memorial. The latter choice was indicated by a surprising 10 to 20 percent, depending on size of school. As for programs within the university, about 40 percent indicated that they were planning to take science oriented programs (including engineering, nursing, and medicine). About 35 percent of those planning to take other post-secondary programs also indicated that they were interested in engineering or medical technologies. Slightly more females than males expressed interest in science-oriented university programs. In the non-university programs, the sex division was clearly along medical versus engineering technology lines, with the former being overwhelmingly female and the latter almost exclusively male.

Students hold generally positive views about the importance of education and of mathematics and science. Most reported that they try to do well in school, and that their parents are interested in and encourage their school work. It is interesting to note the contrast between these opinions and the opinions of teachers. On the other hand, in an opinion consistent with that of teachers, many students indicated that they do not work hard enough, and that they spend relatively little time, an average of about 5 hours per week, on homework.

Student responses to items on teaching practices suggest that most classroom work is of the lecture/note-taking variety, and that most studying takes the form of going over notes from class. Laboratory activities in science are relatively infrequent, averaging about ten per year. More labs are conducted in large schools than in small ones. Students reported that frequent homework assignments (after most classes) are given in mathematics, but that such assignments are less frequent in science. As for homework correction, the most common technique reported was student correction in class (i.e. from answers called out by the teacher). Teachers and friends were reported to be the main sources of help with homework. Help from parents or other adults in the home is relatively rare. In fact, only about one-third of the students (though nearly half of those from large schools) reported having anyone at home who could help them with homework in mathematics.

Primary/Elementary Teacher Survey

Conducting a survey of primary and elementary teachers proved to be a somewhat more difficult task than for high school teachers, because the target population was less well defined and because those at the primary/elementary level obviously held a less direct stake in the study than others who were surveyed. Of an estimated 1500 potentially valid respondents in a sample of 100 schools selected for the survey, only 596 responses were received. Because of the smaller sample size and, more important, because of possible bias due to low response rates, the results of this survey are substantially less accurate than those of the other surveys conducted. Nevertheless, the survey served to corroborate data from other sources, and to indicate areas in which there is a clear direction in opinion and clearly identifiable problems in mathematics and science teaching at this level.

As expected, most respondents were female, over 35 years of age, and had been teaching for more than 14 years. This is consistent with the general profile of primary/elementary teachers. Most teachers had quite limited backgrounds in science and mathematics, despite their generally high levels of certification. As for high school teachers, though to a much more extreme degree, high position on the certification/ salary scale is not necessarily associated with specific qualifications in the subjects of interest here.

There was general agreement that both mathematics and science are important parts of the curriculum. As for the objectives of mathematics and science, the prevailing view was the that highest priority should be on objectives having to do with attitudes, relating science to the world around us, and for mathematics, development of the concept of number. As for obstacles to attaining these objectives, teachers considered the availability of resources and limited student abilities to be the most significant. Elementary teachers also tended to rate resources, teacher background, and student interest as important obstacles.

Instructional practices varied with subject and level. Substantial time in primary mathematics was reported being spent on manipulation of materials, an activity quite consistent with the structure of the new program introduced in the past year. On the other hand, elementary teachers reported spending much less time on manipulation, and much more on presentation and seatwork. Most of the time in primary science was reported as being spent on teacher presentation and discussion. At the elementary level there was a shift towards even more presentation and teacher demonstration.

Teachers were somewhat critical of both their preservice and continuing teacher education. A notable exception was the response of primary teachers to the work done in introducing the new primary mathematics program. This suggests that activities which concentrate directly on an immediate issue may be seen as more useful than the more generic activities associated with much inservice teacher education. Although elementary teachers, in particular, expressed some doubts about their capabilities in science, there was little support for the notion of having specialist teachers at this level.

Post-Secondary Student Survey

First year students at Memorial University, the Cabot Institute, and the Marine Institute were surveyed in September, and again in November, 1988. Students at the Fisher Institute participated only in the November survey. The reason for the two surveys was to determine whether any significant change in perceptions occurred during the first few months of life at these institutions, since this seemed to be the critical transition point in performance. A total of 3232 students participated in the September survey, while a sample of 1975 responded to the November questionnaire.

The survey gave evidence of some bias in choice of post-secondary institutions and programs. Students at Memorial University tend to be disproportionately from larger schools and communities, particularly on the Avalon Peninsula (except for the Grenfell College, where most are from the West Coast). Those at other institutions are more likely to be from smaller communities. University students are also more likely to come from families where the parents are themselves university graduates, and where parents are in professional occupations. A much higher proportion of university students than those at other institutions come to post-secondary education directly from high school.

Students generally held positive views of their high school experiences, and positive opinions about the importance of mathematics and science. However, there was some evidence of concern with inadequate facilities and lack of time to cover courses properly. On the whole, students did not find mathematics and science in high school to be inordinately difficult personally, although the view was prevalent that students are allowed to pass courses with little understanding of the subject. On an individual level, students reported that they work hard and try for the highest marks. On the other hand, referring to students in general, and not to themselves as individuals, there was a general view that students do not work hard enough in high school. The latter point seems closer to reality, judging from responses to specific questions on the time missed from classes and the time spent on homework and study.

A substantial shift could be detected in responses when the reference point was post-secondary rather than high school programs. In general, the difficulties reported were more acute in mathematics than in science. The prevailing view among students was that they were unprepared for the work expected of them. Courses were seen as substantially more difficult than at the high school level. The pace of content coverage, the absence of time for practice, the lack of one-on-one interaction with instructors, class size, and similar factors were reported as contributing to the difficulties being experienced. Most students reported that they almost never approached their instructors for individual help, with many indicating that they would feel intimidated in doing so.

In general, students reported having to work hard, and expressed the view that they were always behind in their work. However, the reports of time spent on homework and study would suggest that most university students are working no more than 3 - 5 hours per week per course outside of class time. This is somewhat less than the 5 - 6 hours per course conventionally thought of as required. Extrapolating from the course results, and allowing for the fact that many students are taking less than a normal five course load, it is estimated that the average university student works no more than about a 35 hour week. Interestingly, students at the other institutions reported spending similar time outside of class hours, despite having much more class time than their university counterparts.

It is clear that the transition from secondary to post-secondary education is not an easy one for most students. Mathematics and science courses are clearly seen as the source of many of the difficulties. Although students respond to the pressures in a variety of ways, one of the specific effects of this for mathematics and science is a tendency to drop courses in these areas. More important, during the first few months of students' university education there is a substantial decrease in the proportion indicating that they intend to pursue a degree in science. Similar results are not seen at the other institutions because program changes are not easily made. However, it is possible that similar difficulties are at the root of some of the attrition from these institutions.

Post-Secondary Instructor Survey

Although the views of post-secondary instructors were reasonably well represented in submissions, it was judged useful to supplement the submissions by a short survey designed to obtain a more systematic sampling of those involved in teaching first year courses. A total population of 111 first year mathematics and science instructors was identified at Memorial University (including the Grenfell college), the Cabot Institute, and the Marine Institute. A survey instrument sent to all of these instructors yielded a total of 90 responses.

The typical instructor is male, with more than 15 years of teaching experience. Most Memorial University instructors hold Ph.D. degrees, with almost all the remainder having the Master's as the highest degree. About half of those at the other institutes hold master's degrees and half bachelor's degrees. Surprisingly, most instructors reported having some professional teacher education. In fact, almost all instructors at the Cabot and Marine Institute hold degrees in education. Most, including Memorial University professors, have actually taught in elementary or high schools at some time. This point is significant because a widespread view expressed by those in the public school system is that post-secondary instructors are lacking in teaching skills, whatever their subject area expertise.

The pattern of teaching assignments varies with institution and subject. Memorial University instructors reported having to teach many more students than their counterparts at the other institutions. On the other hand, the number of class hours is substantially greater for institute than for university instructors. Within the university, physics instructors reported the largest number of class hours (an average of 15), and those in mathematics the smallest number (an average of 10). University instructors reported spending more time than others in preparation for classes and in administration. In fact, the latter activity, which includes meetings, committee work, and the like, was reported as occupying an average of more than 20 percent of instructors' time at the university, compared to only about 5 percent at the Cabot Institute.

The most common instructional technique reported was lecturing. In most cases, the primary reference material is a commercial textbook, which instructors reported as closely matching the course material. Again, this seems to be contrary to views expressed by students and others about the gap between textbook and course.

Instructors tended to take a somewhat negative view of the abilities of students to handle course material. For the most part, the concern was expressed in terms of lack of preparation, poor study habits, inability to keep up with the pace of instruction, and unwillingness to work hard enough to meet the demands of the courses. Instructors were particularly concerned with the perceived inadequacy of high school programs, expressing the view that marks are generally too high and that courses should be more specifically designed for post-secondary preparation. A substantial majority of instructors were of the opinion that post-secondary entrance requirements should be raised, and that students should be admitted to courses only if they meet specific prerequisites. Instructors also felt strongly that courses should not be modified to accommodate variation in preparedness of students, but that special courses should be used to bridge the gap.

All of this confirms the views expressed in the post-secondary submissions, and underlines the substantial gap in thinking between those in the school system and those in the post-secondary institutions. In many ways, this difference in perceptions is as important as any real gap in curriculum content or teaching practices. It is obvious that the two main professional groups need to understand each other better, as well as understanding the needs of society, before progress can be made in solving more substantive problems.

PART III

AN AGENDA FOR CHANGE

CHAPTER 7

REASONS FOR LOW SUCCESS IN FIRST-YEAR MATHEMATICS

The general position taken in this report is that academic performance at all levels in mathematics and science leaves much to be desired. This position has been clearly documented in Chapter 4. Most of the remainder of the report is devoted to an examination of specific aspects of the educational system in which improvements are required if this situation is to be improved.

In the broad context, the specific issue of high failure rates in first-year post-secondary mathematics courses is only a small part of the problem. Nevertheless, the question of why so many students are failing first year mathematics was obviously a major consideration in establishing the Task Force. It is also clear that this question was uppermost in the minds of most of those interviewed or making submissions. It is therefore important that this question be addressed directly, and not subsumed under the broader questions which arise from the overall investigation. A large number of specific explanations were presented to the Task Force during the course of its investigation. Other possibilities suggested themselves as the data were examined. All of these possibilities were treated as working hypotheses to be considered in the study. This chapter looks at those hypotheses judged to be worth attention. The process is one of attempting to rule out the least plausible and retain for further consideration the most plausible of these hypotheses. Only in this manner can we be sure that all of the important ground has been covered.

Is Mathematics Inherently Difficult?

One of the enduring myths of schooling is that mathematics is the most difficult of subjects. It is a commonly held belief that there is something about mathematics which makes it fundamentally more difficult than other subjects. Some argue that the abstract nature of the subject is the cause of this problem. Others insist that it is the cumulative nature of mathematics which causes difficulty. Related to this is the argument that mathematics involves essentially a new language - one for which there is little opportunity for practice outside the school setting. A further line of argument is that mathematical capability is the preserve of those who are especially intelligent, or that some students have a natural talent for mathematics and others do not.

At the most fundamental level, there is no way to answer this question. We simply do not know enough about basic mental processes to be able to say that those processes involved in mathematical learning are essentially different from those concerned, say, with language learning. Nevertheless, there are close parallels between mathematical symbolism and logic and other forms of intellectual activity. Almost all intellectual activity is symbolic in one way or another. The letters of the alphabet are no less symbolic than plus or minus signs or other mathematical symbols. There is little reason to believe that arithmetic operations such as addition or multiplication, or their algebraic equivalents, are more abstract than sentence structures or grammatical conventions. Mathematical reasoning is essentially the application of a formal symbol system and certain rules of logic, in the same way that writing a sentence involves symbols and rules of logic. Indeed, more than most other formal systems, mathematics has a direct connection to the observable physical world, in such areas as counting and measurement. It therefore seems safe to argue that any difficulties with mathematics in school are unlikely to be inherent in the nature of the subject.

At the same time, there are features of mathematics which might contribute to difficulty in practice, if not fundamentally. Most aspects of mathematics, other than perhaps counting, are not reinforced at almost every waking moment, in the sense that this is true for language. Children who must struggle to form coherent sentences at every turn, from the time they can talk, do not have to do the same thing for addition or multiplication. At a later stage, reading and oral communication take on fairly sophisticated forms in settings where it would be unheard of to have to solve an algebraic equation. Furthermore, to a greater degree than is true for language, mathematics is intolerant of small lapses in rules or in logic.

This leads us to argue that mathematics is fundamentally a school subject, in the sense that children do not encounter mathematics, except in the most rudimentary way, in settings other than school. There is no mathematical equivalent of the bedtime story. Parents do not correct their children's addition or multiplication in the way they do their grammar. It is difficult to imagine an individual acquiring any kind of facility with mathematics, comparable to that with oral language for example, except in a school setting. The closest equivalent to learning mathematics in school is perhaps learning a second language, which is not spoken in the home or community. The demands made on most children in mathematics are, however, far in excess of what is usually expected in second language learning. Under the circumstances, it is not surprising that difficulties are encountered.

We can therefore acknowledge the existence of difficulties in mathematics without having to assume that these are in any way inherent in the subject. If school is the primary, indeed the only, place in which mathematical knowledge can be acquired for most people, it is necessary to ensure that the best possible conditions prevail in the schools. This is essentially what the rest of this report is about. At the same time, it must be recognized that fundamental restrictions of time, resources, and knowledge about how best to teach mathematics are the limiting factors in the ability of the education system to provide optimum learning conditions.

In any case, the argument about inherent difficulty does nothing to explain why so many students fail at the first year post-secondary level and not at other places in the system. It seems implausible to suggest that cumulative difficulties would suddenly lead to catastrophic results at this level. This leads us to suggest that the difficulty has something to do with the way mathematics is treated at the interface between secondary and post-secondary education. The remaining questions raised in this chapter all relate to this possibility.

Are Post-Secondary Admissions Standards too Low?

One of the common arguments made to the Task Force was that many students now finding their way into post-secondary education do not belong there, and that the source of many of our problems in mathematics lies in liberal admissions standards. A number of calls were made for increasing the high school average required for admission to university, for imposing specific requirements in certain courses, or for establishing enrolment quotas.

We have already adopted the basic principle that we should be attempting to increase rather than restrict participation in post-secondary education. Problems of performance are not solved by simply keeping poor performers out of the system. This denies access to educational and career opportunities, perpetuates low expectations for those denied access, and most important, flies in the face of the need for a more educated populace. We must solve problems of poor performance by improving performance, not by restricting admission to the higher levels of education. Any gap between high school and post-secondary expectations must be closed. We should not create an illusion of high performance by denial of access.

Aside from the basic principle, there is reason to reject this argument on empirical grounds. As the data in Chapter 4 indicate, no overall decline in first year university performance has accompanied the increase in admissions in recent years. The observed decline is unique to mathematics, and even more specifically to the main first semester course. It is possible, of course, that other disciplines have found ways to compensate for any decline in student abilities. This seems implausible, however, as there is little to suggest that other disciplines would be any more inclined than mathematics to depress their expectations to fit any drop in quality of students admitted. This is especially so in science courses, where expectations are established in relation to the demands of more senior courses and of the professional schools. This leaves the argument that the decline in mathematics success has more to do with the specifics of the mathematics program than with any general decline in student abilities.

In concentrating on the decline in mathematics scores, there is a tendency to overlook the more important point that success rates in mathematics have never been as high as those in other subjects. Again, this reinforces the argument that the problem is unique to mathematics. In keeping with the general principle that success rates of 80 percent or so should be expected, proposals for improving the situation in mathematics must not only be aimed at reversing the current decline, but at bringing success rates to a level comparable to those in other disciplines.

Are First Year Mathematics Expectations too High?

One of the complaints presented to the Task Force is that post-secondary institutions expect too much of their students in mathematics. Specific mention was made of the rapid pace at which content is covered in first year university courses, and about the adjustments students must make from a setting with strong support to one of independence.

At the most basic level, this argument relates to the question of what level of mathematics knowledge should be expected of students. As has already been argued, there is no absolute answer to this question. In practice, the requirements for first-year courses are determined by various factors outside the control of those responsible for these courses. In the university, professional faculties establish their own entrance requirements. In most cases, these include the completion of a course in calculus. In other institutions, the demands of technical courses and the requirements of external accrediting agencies are the determining factors.

An important point to be made here is that our analysis has revealed little evidence of a major shift in expectations within the past few years. Until the Fall of 1988, course content and examination practices at the university had been almost constant for a decade. This is also true for courses at other institutions. There have certainly been no shifts of content sufficient to account for the decline in success rates. This is not to say that conditions are exactly what they were a decade ago. In particular, it is clear that there has been some deterioration in teaching conditions at Memorial University, though not at the other institutions. This is not a matter of expectations, however, and is something which must be examined separately.

In any case, it is not reasonable to expect post-secondary institutions in this province to have lower requirements than those at comparable institutions elsewhere in Canada. Graduates of these institutions should be expected to possess knowledge and skill comparable to their counterparts elsewhere. Our analysis of mathematics curriculum at other universities in Canada (**Background Report #5**) shows clearly that Memorial's requirements are, in fact, slightly below those of most others. In particular, the general expectation across the country is that students entering university be prepared to take calculus from the beginning, without having to take a pre-calculus algebra course. The latter type of course is offered in many universities only for students who do not enter from the normal high school stream within the province in which the university is located, whereas at Memorial, this is the essential first course.

We could, of course, call into question the entire structure of mathematics at this level, and argue that all universities are expecting too much. Besides being a somewhat futile exercise, this stance would also contradict the basic principle that we should aim for the highest, not the lowest, possible levels of achievement. What is important to recognize is that, although success rates in first year mathematics across the country are lower than those in other subjects, they are almost universally higher than those in this province. The same is true for performance at other levels, as has been demonstrated in Chapter 4. It would be an obvious disservice to students to advocate acceptance of existing levels of performance as adequate or inevitable. The argument that expectations are too high must be rejected.

Are Secondary School Expectations too Low?

This is the opposite side of the above argument. In fact, it might appear that having rejected the hypothesis of too high post-secondary expectations we must accept this opposite view. This is not necessarily the case, however, as we shall see in other sections of this chapter. Nevertheless, a careful analysis of the situation in the high schools is necessary, if only because there is a strong body of opinion which holds that the problem of failure indeed has its origin in the changes in mathematics which occurred when the revised high school program was introduced.

Again, it is instructive to look at the situation in other provinces. In general, the structure of mathematics programs is similar across Canada, with most provinces having the equivalent of Newfoundland's academic and advanced mathematics. Topics offered in the courses are fairly similar. The main difference seems to be in the proportions of students enroled in the more rigorous course. In most provinces this proportion is far higher than in Newfoundland. In addition, four provinces offer an even more advanced course, which includes calculus. Students intending to pursue post-secondary studies in mathematics and science are encouraged to take such a course. In Ontario, this course is required of all students entering university. In effect, what we see in several provinces is a course roughly equivalent to our advanced mathematics for most post-secondary bound students, and a further course, which includes calculus, for academically superior students. It is clear that students from this province would be at some disadvantage in entering universities in other provinces which assume that the equivalent of advanced mathematics has been completed.

One of the most persistent points made in submissions and interviews concerned the wide gap between secondary and post-secondary expectations. Obviously, most of those concerned feel that their particular set of expectations are the most realistic. In fact, as shown in Chapter 6, there was a striking contrast between secondary and post-secondary groups on this point. Most of those in the high school system believe that the university, in particular, is expecting far too much of students in their first semester. Post-secondary officials, on the other hand, feel that their expectations are at best barely adequate, and that high school standards leave much to be desired. As we can see, the comparative data tend to support the latter view. In the next section, an attempt is made to document a specific instance of the impact of low expectations.

Academic versus Advanced Mathematics

Part of the problem of high school expectations lies in the decisions made about access to the advanced mathematics course. It seems to be an unwritten rule in this province that advanced mathematics is designed for only the top 15-20 percent of high school

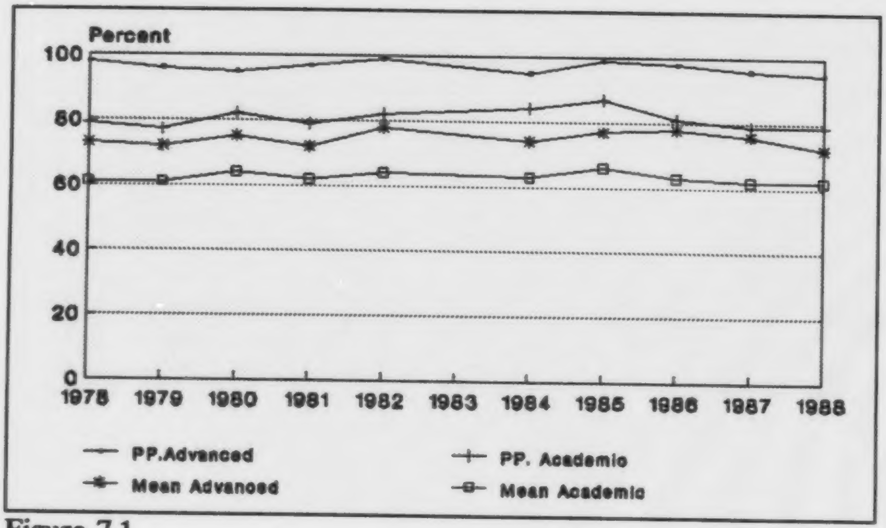

Figure 7.1
Mean Scores and Percentage Passes, Advanced and Academic Mathematics, 1978-1988

students. Certainly many of the teachers interviewed were strongly of the view that others would have great difficulty coping with the course. The failure to offer this course in many schools is based on the assumption that the expected proportion would yield too small a group to justify allocating a teacher to the course. The comparative data suggests the possibility that part of the problem locally may lie in our judgement of the proportion of students capable of handling advanced mathematics. Furthermore, there is some question of whether the course is, in fact, taken mainly by those in the expected target group. This issue therefore requires further analysis.

The first clue that advanced mathematics may be undersubscribed lies in the public examination results for advanced versus academic mathematics. These were given in Chapter 4, but are shown again in Figure 7.1, in a format which permits direct comparison. As we can see from this graph, both the percentage passing and the mean score for advanced mathematics are substantially higher than for the academic course. Virtually nobody fails advanced mathematics, and the mean score is notably higher than for any other public examinations subject.

This is clearly contrary to the notion that advanced mathematics is a high risk course. Even if we acknowledge that higher ability students are more likely to take advanced mathematics, we would expect this to be offset by the increased difficulty of the course. Under current circumstances, advanced mathematics is virtually a no-risk course for those who take it. Given the variety of reasons, other than special aptitude for mathematics, which might lead a student to take this course, and the errors in prediction which might be made in advising students about this selection when they are in grade 10, it seems sensible to argue that the reasons for high performance do not lie entirely in exceptional talent.

If this were true, a drop in success rates should have occurred in this course over the past few years, as larger numbers of students have elected to take the course. While there has been a slight decline over the past couple of years, success rates are now as high as they were in the early 1980s, when many fewer students were enroled. Success rates, in fact, appear to follow a cyclic pattern of small increases and decreases, unrelated to changes in enrolment. The important point is that success rates in advanced mathematics are exceptionally high. Even if the highest ability students are being selected into the course, it is clear that the cutoff point for selection could be reduced substantially without creating undue risk that many students will fail.

Evidence that high scores in advanced mathematics are not due to the selection of exceptionally mathematically talented students is also found in the relationship between mathematics performance and performance in other high school subjects. If such talent were subject-specific, one would expect a low correlation between mathematics scores and those in other subjects. This is not the case. Correlations of the order of .50 are found between mathematics and high school average, for students in both mathematics courses. That is, high school average seems to be a reasonably good predictor of mathematics performance.

In order to obtain an estimate of the underlying academic capabilities of those taking the two courses, the overall average in

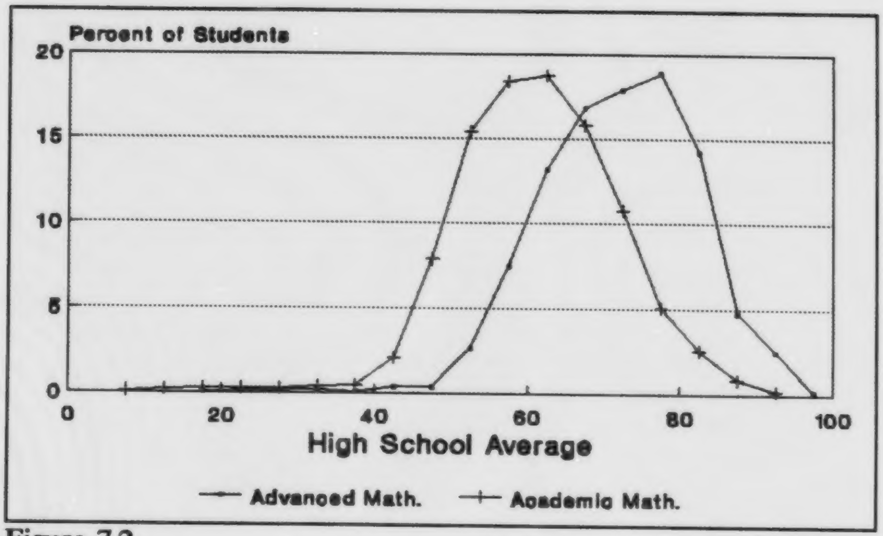

Figure 7.2
Distribution of High School Averages of Advanced and Academic Mathematics Students

public examination courses for the two groups was compared. The distributions of these scores are shown in Figure 7.2. What is surprising about these figures is the size of the overlap between the two distributions. Although, on average, advanced mathematics students do better than those in the academic course, there is substantial overlap in the distributions. Advanced mathematics, in fact, seems to be taken by students having a wide range of abilities. Given the size of the correlations between mathematics scores and overall averages, this suggests that a much larger number of students could be expected to perform at acceptable levels in advanced mathematics.

As it happens, our interviews, along with data on the availability of advanced mathematics in the schools, give reason to believe that the decision to take advanced mathematics is based on a wide variety of considerations other than specific mathematical talent. Whether or not the course is available is one of the most obvious of these considerations. However, this is by no means the only reason. In fact, the proportion of students taking this course varies widely, even in schools where it is available. Parental decisions, peer influences, the guidance given in schools, considerations of post-secondary programs, and many other factors influence student choices.

All of these considerations lead to the conclusion that many more students could actually cope successfully with advanced mathematics than now choose the course. An analysis designed to predict the appropriate cutoff point for selection into the advanced course has shown that if all students with a high school average of 60 percent or more were channelled into this course, success rates would be at a level comparable to that now experienced in academic mathematics. If this were done, the proportion of students taking this course would increase from its current 20% or so to more than 50%.

Taking this line of argument a step further, there is a compelling argument for dropping the academic mathematics course altogether. If 50% or so of all students could succeed in advanced mathematics under current conditions, many more might succeed if conditions were improved along lines to be developed in subsequent chapters. If, as the post-secondary institutions have argued, advanced mathematics is the most appropriate prerequisite for their programs, then it is questionable if any student who might wish to enter these institutions should be denied an opportunity to take the course. Since almost all students are at least considering continuing their education beyond high school, and since more than half do attend institutions which demand high levels of mathematical capability, it makes sense to increase drastically the participation rate in advanced mathematics.

One of the most attractive aspects of this shift is that this essentially solves the problem of the availability of this course in small schools. Under the conditions just described, the balance of enrolments would shift so strongly in favour of advanced mathematics that even the smallest schools would find it both possible and necessary to offer the course. If any course had to be sacrificed because of small numbers advanced mathematics would not be the one.

There is, of course, no compelling reason why the course which remains if the current academic mathematics is dropped should be exactly the same as the current advanced course. The important consideration here is that the course be considered appropriate as a prerequisite for first year post-secondary courses, and that the latter courses be at a level comparable to those at universities and other post-secondary institutions across Canada. Essentially, what is required is a redesign of the program to yield a single course at a level suitable for post-secondary entrance, to be taught under conditions which will ensure high success rates. Close collaboration between the secondary and post-secondary levels will be required to work out the details of such a course.

There are, of course some arguments against such a shift. The problem of failure in mathematics obviously should not be transferred from the post-secondary level to the high schools. Nor would it be desirable to have mathematics become a major obstacle to high school graduation for students who will not continue their education. Neither of these is seen as necessary or inevitable. The above analysis suggests that we have vastly underestimated the ability of students to cope with high school mathematics. It is certainly better to address the problem at the high school level than to allow it to accumulate with disastrous results later. A core element in this analysis is that increased expectations will be met by improvements in performance. In many ways, instructional conditions in high schools are already better than those in the post-secondary institutions, particularly the university. Further improvements can be made to reduce the risk that large numbers of students will fail high school mathematics, even if the common course does become the equivalent of the current advanced mathematics.

As for mathematics being an obstacle to graduation, it can be argued that students with no plans for post-secondary education already have another route to completing the mathematics requirements, even if these are increased as suggested earlier. The greatest problem here is identifying such students, given that almost all students seem to be at least considering the post-secondary option. It seems to make sense to err on the side of allowing students to attempt the highest level course, rather than reducing student options from the beginning of high school. As will be argued in subsequent chapters, what is needed is to build the conditions for higher levels of attainment, rather than accepting low levels as inevitable for large numbers of students.

Perhaps the most serious argument against a drastic shift towards advanced mathematics is the question of whether high school teachers can be expected to cope with the course. The matter of teacher qualifications will be addressed in detail in a later chapter. Suffice it to say that this is likely to present a problem for some schools, at least in the short term. At the same time, many classes of academic mathematics are now being taught by teachers who are quite well qualified and who are now teaching the advanced course in any case. Simply shifting the proportions will present few problems in schools already offering advanced mathematics. In the final analysis, the shift from academic to advanced in not a very drastic one for a teacher. It might be argued that teachers capable of handling one course ought to be able to handle the other. The problem of teacher qualifications should not be regarded as a course-specific one. In any case, we must work towards improving teacher qualifications generally, rather than limiting student opportunities because of teacher limitations.

On balance, therefore, the advantages of moving to a common mathematics course equivalent to the current advanced mathematics far outweigh the disadvantages. The advantages are fundamental. The disadvantages can and should be overcome.

Shifts in Policies and Practices

The concern here is with the narrow question of whether there have been specific shifts of policy or practice in recent years which might be expected to contribute to the continuing decline in success rates in mathematics.

At the high school level, the main shift which can be detected is a reduction in time for mathematics instruction which accompanied the revised high school program. Since this shift occurred at a particular point in time, one would expect that its effect would have been felt at that time, in the form of a sudden drop in performance. This is not what has happened, however. No major discontinuity can be detected in performance in 1983, the year this change took effect. The decline in post-secondary success rates began before this shift, and has continued ever since. As will be argued later, loss of time is a serious matter. However, this does not seem to be the major cause of the trend towards lower success rates. If an argument is to be made for increased time allocations, it should be in the context of bringing about overall improvements in performance, along the lines already developed.

A trend which is more consistent with a gradual decline has, however, been occurring at Memorial University. Increased enrolments in recent years have not been accompanied by comparable increases in staff in the Mathematics Department. Class sizes and total student loads for instructors have increased substantially. In addition, the demise of the Junior Division and the resulting integration of staff have created a climate in which first year courses no longer receive special attention in terms of quality of teaching. Associated with these changes has been the virtual abandonment of the foundation course as an option for students having special difficulties. Finally, the attempts which have been made to compensate for the weaknesses of incoming students seem to have been halfhearted at best and pedagogically unsound at worst. For example, reliance on a help centre, where students can appear voluntarily, is a poor substitute for organized problem-solving sessions. Similarly, the practice of placing all repeaters in a single large course section, though convenient, is not likely to enhance the self-esteem of these students or allow for adjustments in teaching practices to overcome weaknesses. Again, all of these points require further attention. It is not difficult to imagine, however, how all of this could contribute to an overall decline in teaching quality and hence in student performance.

No similar shifts can be identified at the other post-secondary institutions. In fact, the conditions of instruction in these institutions are judged to be significantly superior to those in either the high schools or the university. The Cabot and Marine Institutes have highly qualified instructors, relatively small classes, student groups with specialized interests, and ample time compared to the university.

The only major change which could be detected is a shift in admissions policy at the Cabot Institute from academic standing to first-come-first-served as the basis for admission, which occurred in 1985. Like the change in time in the high schools, however, it is not possible to detect any significant discontinuity following this change. The gradual deterioration in performance at the Cabot Institute predates this shift, and has continued since that time. It can only be concluded that the decline is associated more generally with declining expectations in the high schools, as already indicated, rather than with conditions at the Cabot Institute itself.

This, of course, does not explain why no comparable decline has occurred at the Marine Institute. It is difficult to make any judgement on an institution which accepts such a small number of students, and whose clientele is more mature, not having entered the institution directly from high school. We would only remark that teaching conditions seem to have improved somewhat at the Marine Institute in the past few years, especially with the move to the new campus. The Marine Institute has also worked towards course consolidation, and has in place a more comprehensive program of individual student help than exists elsewhere. Again, however it is not possible to make any direct connection between conditions at the Marine Institute and the relative stability of success rates.

Examination Practices

The discussion in Chapter 4 of the interpretations of test scores opens the possibility that the higher failure rates of recent years may somehow be a function of subtle shifts in test difficulty, grading practices, or other aspects of evaluation. As will be discussed in Chapter 11, there is evidence that the remarkable stability of high school marks is related to such factors. Is it possible that the downward trend in post-secondary grades has similar origins?

An analysis of examination papers in Mathematics 1010 over a period of about a decade revealed no obvious systematic shifts. Nevertheless, the papers were different enough from year to year to suggest that some fluctuations could be expected. Such fluctuations have appeared from year to year, but these are not sufficient to override the general downward trend. However, the possibility of shifts in marking schemes could not be ruled out because student papers were not available for analysis, and no records exist of the specific marking schemes used. Interviews with post-secondary instructors suggest that marking may have become slightly more lenient in recent years, as instructors look for ways to give students the benefit of the doubt. Obviously this tendency, if it does exist, has not been sufficient to override the overall trend. In any case, it is clear that university examinations have remained essentially criterion-referenced, and that instructors oppose any form of scaling as a way of increasing success rates.

Overall, therefore, it appears that a shift in examinations is not a major contributor to the decline in success rates. This is not to say that all is well with university evaluation practices, however. Although the university has resisted the tendency towards normative interpretations, examinations at the post-secondary level suffer from most of the problems of the public examinations. These problems are discussed in more detail in a subsequent chapter.

Course Pacing and Workload Requirements

There seems to be general agreement that the pace of coverage of course content is much more rapid at the university than at the high school level. In fact, a comparison of Mathematics 1010 or 1080 with the high school advanced mathematics course suggests that almost as much content is being covered in about 36 hours of class time at the university than is treated in 100 hours or so in the high school. Class time in the university course is occupied almost exclusively in covering new material, primarily through teacher lectures. In the high school, a substantial amount of class time is spent in review, practice exercises, unit tests, reteaching, and other activities. Research also suggests that in the high school, the pace is determined by the lowest ability students in the class. In the university setting, little account is taken of the entry abilities of students or of variations in student background. It is also expected that practice, relearning, preparation for tests, and the like are to be done outside of class time.

Whether the pace at the university is too rapid or that at the high school level too slow is a matter of some debate. Most university instructors would argue that it is essential to maintain a rapid pace to ensure that students meet the demands of subsequent levels or that courses are on a par with those in other universities. It is also argued that students should be expected to function independently at this level. Derisive references were frequently made to the tendency of high schools to "spoon feed" students, thereby encouraging a degree of dependence on the teacher which cannot be sustained at the university level.

Students themselves, as well as those associated with the high schools, tended to take the opposite stance. There was almost universal agreement among those outside the university that the latter institution is largely indifferent to the needs and abilities of students, and that instructors simply "plough ahead" in their subject, regardless of whether or not students are keeping up. Students, in particular, were vociferous in their complaints that they are continually behind in their work, and that there is nowhere to turn when they are having difficulty.

Again, this is a matter which will have to be addressed in the chapter on time allocation and use. Suffice it to say here that there is evidence both that students are not working sufficient hours to keep up with university work, and that few provisions are made in the university for supervised practice, review, individual assistance, or other practices designed to enhance learning. A strong case can also be made that class hours are insufficient for the amount of material being covered. There are also indications that conditions have deteriorated at the university in recent years, making it more difficult to provide the needed assistance to students. Overall, it can be said with confidence that existing conditions at the university have contributed substantially to the decline in success rates.

The same cannot be said about the other post-secondary institutions, however. To begin with, these institutions take far more time to cover much less material than is found in university courses. A good deal of time in the first term mathematics courses at the Marine and Cabot Institutes is spent in reviewing concepts from the high school program. While there is no less reason for concern with the limitations of student entry-level capabilities, these institutions have much more scope to address these limitations than is found at the university. Again, however, it must be noted that students at these institutions often have different backgrounds from those coming to the university, and that it is not surprising that high school material would have to be reviewed at greater length.

Student Work Habits

Again, the view was expressed in many submissions that students are no longer prepared to sustain the work levels necessary for success in post-secondary mathematics. Some were of the opinion that this is a consequence of the leisurely pace maintained at the high school level. Others took a much broader view, sounding ominous notes about the loss of the work ethic in our society, or the number of competing influences on students which distract them from academic work. Students themselves were clearly of the view that they work hard but still have difficulty keeping abreast of demands.

Reasonably clear data are available on student workloads in the post-secondary institutions. The average student spends 3-5 hours weekly per course at out-of-class work. Taking the mid-point of this range, adding over a full course load, and adding class time, it can be inferred that the average university student spends 35-40 hours at course work. For students at other post-secondary institutions, the total is estimated at about five hours higher, because of the additional class time required at these institutions. Unfortunately, no data are available on changes in levels of work over time. We are thus unable to say whether the decline in performance is associated with a decline in hours of work. We can say that, although these hours are comparable to those worked by the average person in the labour force, this level of activity is not high by the standards of the professions to which many students aspire, and not consistent with the perception that students are drastically overworked. There is clearly scope for many students to spend more time at their studies, thereby relieving some of the pressure which exists to keep up with the pace demanded.

Summary and Recommendations

This chapter has examined a number of potential causes of the decline in mathematics scores at first-year post-secondary level. An attempt has been made to address factors which seem unique to mathematics and for which changes can be identified which parallel the change in performance levels.

At this stage, the reader may be left with the impression that it is essentially impossible to identify the causes of the problem. This is true in the sense that no single cause has been pinpointed and that no precise estimate has been given of the relative contributions of different factors to the problem. In fact, as has been pointed out earlier, it is essentially impossible to make causal statements after the fact in a situation where there are multiple contributing factors.

Nevertheless, the analysis suggests that there are only two **major** contributors to the problem, with other factors playing a more minor part. The following specific statements make the position clear:

The first major contributor to the decline in success rates in first-year post-secondary mathematics is low expectations in the high schools, and particularly the selection by most students of academic rather than advanced mathematics.

The second major contributing factor is a deterioration in teaching conditions in first-year mathematics courses at Memorial University.

The increased intake of first-year students at Memorial University in recent years is NOT a significant cause of declining success rates, except to the extent that this has contributed to the deterioration of teaching conditions. That is, there is no indication that students now entering the university are fundamentally less able than in the past.

In subsequent chapters, many of the issues discussed here will reappear in the context of the broader problem of how to improve participation and schievement throughout the system. Nevertheless, some specific recommendations seem to be called for at this point, to address the narrower issues discussed in this chapter.

Recommendation 7.1

That the current academic mathematics course be phased out over the next five years, and replaced by a course equivalent in depth to the current advanced mathematics course for all students planning to continue to post-secondary education in the province.

Recommendation 7.2

That the new course be designed by the Department of Education in close collaboration with the mathematics departments of the post-secondary institutions.

Recommendation 7.3

That a transition period of five years from September, 1989 be allowed for introduction of the new course in all schools, before the post-secondary institutions require the revised course for admission.

Recommendation 7.4

That beginning in September, 1989, schools encourage all Level I students who plan to continue to post-secondary education to take advanced mathematics.

Recommendation 7.5

That specific steps, as outlined in subsequent parts of this report, be taken to improve the conditions under which mathematics is taught at Memorial University, with particular emphasis in the short term on improving success for those who have not taken the proposed new high school course.

Recommendation 7.6

That the post-secondary institutions NOT restrict admissions as a means of improving first-year success rates.

CHAPTER 8

THE PROBLEM OF PARTICIPATION

If the first principle of this report is that achievement levels in mathematics and science must be improved, the second is clearly that this ought not to be done by excluding large numbers of students from participating in these areas of the curriculum. In fact, it is clear that substantial increases in participation are required. As indicated in earlier chapters, substantial gains have been made in participation at the high school level, both overall and specifically in mathematics and science. There have also been significant gains in overall university participation. However, these gains have not been translated into increases in the numbers of students choosing science based post-secondary programs. On the surface, therefore, it appears that while the problem of achievement is primarily associated with elementary and secondary education, the immediate problem of participation is largely a post-secondary phenomenon. The main exception to this is the situation in small schools. This chapter examines some of the issues of participation, and presents a number of recommendations designed to improve participation rates.

Secondary versus Post-Secondary Participation

The basic data on participation rates in mathematics and science at all levels of the system were presented in Chapter 5. To reiterate briefly, the data show that the number of students taking high school science courses, particularly physics and chemistry, has increased substantially over the past few years. Advanced mathematics has also increased slightly, although not at the rate that has been argued for in the previous chapter. At the same time, access to most courses, especially advanced mathematics, physics and chemistry, is severely restricted in small schools.

On the other hand, despite increases in overall enrolments at Memorial University, participation in first-year mathematics and science courses has shown a decline beginning about three years ago. At the graduation level, the numbers in the physical sciences, in particular, have always been small, and have not increased in recent years. An average of ten or so graduates in physics and chemistry is all that remains of the many hundreds found in these courses at the first year level. A decrease in the number of declared majors indicates that this trend is likely to continue for the next several years.

One of the most striking findings of the student surveys was the drop from September to November in the number indicating that they intended to pursue science based programs, and the increase in the number of students with negative views on further work in this area. It is clear that something occurs during the first couple of months of post-secondary education which leads many students to change their minds about pursuing science programs, and to develop negative views. Both the surveys and the focus group interviews suggest that this has to do with the demands of science courses and the perceived quality of instruction. More directly, it is obvious that the high failure rate in mathematics immediately limits the options of many students, as mathematics is a prerequisite to all further work in science.

The picture at other post-secondary institutions is similar in terms of attitudes but has rather different consequences in terms of program. A university student has the option of simply switching degree programs or majors at any time. While this may sometimes require extra courses, it rarely leads to a complete loss of courses already taken. This route is simply not available to students in technology or applied arts programs. Students who find themselves in the wrong programs have no real option except to drop out and perhaps try another program at some future date. This immediately suggests that the high attrition rates at the Marine and Cabot Institutes may be linked to program inflexibility. Whether or not this is the case, there is reason to argue that first year programs at these institutions should be more flexible.

What is clear is that the shift in thinking during the first term in the post-secondary institutions is part of a broader problem of transition from secondary to post-secondary education. Despite now having an extra year in school compared to a few years ago, it is clear that students are generally not well prepared for the rigors of post-secondary education. Indeed, some (including students themselves) have argued that the additional year has accomplished the reverse of its intended purpose, by allowing the secondary school program to be completed at a slower pace. If the general thrust of this report is accepted, this situation can be expected to change significantly in the future.

It is critical that we find a way to capitalize on the substantial enthusiasm which seems to exist for science and science based professions among students graduating from high school, and that we remove the conditions which lead to this enthusiasm being diminished early in students' post-secondary careers. Some might argue that the interest in these areas among high school students is a function of the relative ease with which they can succeed in mathematics and science at the high school level. If this is so, we are faced with a serious dilemma. Increased rigour in high school programs might simply transfer the problem of loss of interest to the high school level.

Fortunately, we do not believe that this is inevitably the case. One of our basic principles is that high achievement and high participation do not have to be mutually exclusive. What is required is to program design and teaching conditions which maximize both. Much of the remainder of the report addresses such conditions, mainly as they apply to primary/elementary and secondary schools. In this chapter, specific proposals are presented which are aimed at creating a smoother transition between secondary and post-secondary education. At the same time, specific emphasis is placed on bringing about high levels of attainment and participation in science based programs. These proposals are based on finding a solution to the problem of lack of access of programs in small schools, finding a role for the community colleges, and providing special incentives for the most talented students to enter science programs.

Small Schools

Small schools have always been part of the educational scene in this province. The number of such schools declined drastically during the period of consolidation of the 1960s and 1970s. Nevertheless, a combination of factors such as geography, declining enrolments, and denominational jurisdiction creates conditions whereby the number of such schools remains fairly large. In 1988, for example, there were approximately 75 high schools with fewer than 25 students in the graduating class. This number is likely to increase in the next few years as enrolment continues to decline, and as people continue to move from rural communities.

Since the revised high school program was introduced, one of the most serious concerns of school districts has been with providing access to a variety of courses in small schools, sufficient to give students in these schools reasonably equal treatment compared to their counterparts in larger centres. Schools have resorted to a variety of ingenious arrangements to maximize course offerings. The data indicate that there has been some success in this effort in the case of mathematics and science. Nevertheless, the proportion of small schools offering certain crucial courses remains much below that for larger schools. Our interviews suggest that school districts are faced with an almost insurmountable problem in attempting to staff their small schools, despite the provisions which exist for additional teacher allocations for such schools.

On the surface, it might appear as if our proposal for a common academic program would help alleviate this problem. However, even the most restricted academic program would be expected to provide for several science courses, and perhaps two types of mathematics course. In a school with, say, 20 grade 12 students, even one split of this group to allow course choice results in classes of 10 or fewer. While such small classes have distinct advantages, the problem is that it is essentially impossible to deploy staff or find the time or classroom space to make such small groups viable. In addition, the capabilities of teachers are stretched beyond reasonable limits when individuals are asked to teach a disparate collection of subjects, some of which lie well outside the areas in which they have been trained. It is simply impossible to expect teachers to cope with the kinds of assignments which are frequently found in small schools.

Over the past year, an attempt has been made to offer the advanced mathematics course to students in small schools through distance education, using audio/visual telecommunications technology. Considerable effort has been put into the development of the system and the preparation of student materials for the course. Consideration is being given to making other courses available in the same manner.

On the surface, distance education has some attractions. Courses can be made available in even the smallest communities. The best instructors can be assigned to the preparation and delivery of courses. There may even be subject areas, including science, in which the use of video technology can enhance the quality of instruction (although the technology currently in use does not lend itself to this). Overall, however, the technology is essentially experimental, and a strong argument can be made that mathematics and science are the wrong subjects for such experimentation. There is a serious risk in the current work that it will be made to appear successful by modifying the course to accommodate the limitations of the technology.

Furthermore, it is not at all obvious that the cost of such programs will be reasonable, even when the programs are put into full operation. Certainly the startup costs of such programs are such that fairly large numbers of participants are needed to make the initial outlay worthwhile. Even the operating costs are relatively high, and relatively insensitive to the number of participants. If such courses are to be offered only under extreme conditions in small schools, it is doubtful if participation would ever be high enough to offset the costs. It is unlikely, for example, that such courses would be used when any other alternative is available, a point which underscores the last resort nature of such an approach. On balance, it is difficult to make a case that distance education can solve many of the problems of access to broadened programs.

From the point of view of access to programs and of promoting achievement, it seems to make sense to abandon attempts to do the impossible by offering broad program choice in small schools. This leaves two alternatives, other than distance education. The first is to find ways in which students can attend larger schools for the last couple of years of secondary education. The second is to refine the concept of a core program and to find ways to offer this program in all schools.

In some cases, the first could be accomplished fairly easily, through denominational cooperation or further school consolidation. In other cases, however, this would require students to leave home for the last part of their high school education. Unfortunately, to adopt the latter as a general means of improving access would fly in the face of some firmly entrenched features of community and educational life in the province. To begin with, schools are powerful symbols of community viability. It is obvious that any proposal to move students away from home for secondary education would be viewed as a death sentence for some communities. In many areas, it is already obvious that school consolidation has proceeded as far as communities will tolerate, if not as far as existing transportation systems might allow.

In any case, the public policy issues underlying the further consolidation of schools go well beyond the mandate of this investigation. There is therefore some obligation to provide an alternative to this strategy. This leads to an argument for defining a minimum program sufficient to meet the basic requirements of high school graduation and post-secondary access, and developing the means of delivering such a program in all schools. This argument has several main threads. First, it is necessary to abandon the idea of dividing already small classes of students into still smaller groups to allow for program choice. Second, it is necessary to work, for the most part, with existing school staffs, and to provide the training required so that these teachers can deliver the basic program. Third, the core program must include courses which have previously been considered impossible to deliver in some schools. This is especially true for specific science courses, if the goal of having a program meeting post-secondary requirements and the needs of society is to be met. Other courses will simply have to be abandoned to avoid having groups too small to justify assigning a teacher. Finally, it is necessary to establish teaching conditions such that most students can succeed in courses which they might otherwise avoid.

The details of courses, teacher training strategies, and other aspects of this proposition will be examined in subsequent chapters.

The general principles are embodied in the following recommendations:

Recommendation 8.1

That attempts to offer program choice in schools with fewer than 20 students in the grade 12 graduating class be abandoned in favour of a core program available to all students.

Recommendation 8.2

That the core program include the revised advanced mathematics course plus physics or chemistry.

The second recommendation requires some explanation, as it represents a major departure from existing thinking and practices. It has long been assumed that one of the major problems of small schools has been the inability to offer the courses mentioned in this recommendation. While there are various reasons why this has been the case, one of the main ones has been the assumption that only a small proportion of students can be expected to cope with such courses. It follows that the number of candidates for these courses in small schools is often insufficient to make the courses viable.

In this report, we have operated from a fundamentally different premise, namely that there should be higher expectations of student ability, and that the system should be designed to ensure high participation and success in basic academic core programs. In the past, the school system has tended to err on the side of exclusion of students from the highest level courses. The argument here is that this should be reversed, and that all students should be given an opportunity to take such courses. Students in small schools are no exception to this. If this line of argument is accepted, schools must offer specialized sciences, along with the other core courses. This becomes a much more viable proposition if such courses are taught to all students, rather than attempting to divide already small groups.

Once this basic principle is accepted, then it becomes possible to concentrate on a much narrower set of problems of implementing programs in small schools. For example, instead of being concerned with ever increased need for broadening staff capabilities or facilities, we can focus on what is needed to service the core program. Furthermore, the notion that students from such schools are inherently disadvantaged by lack of program availability is replaced by one which highlights the distinct advantages in having all students take a program which opens rather than closes their future options.

Community Colleges and First Year University Programs

For the past several years, all of the province's post-secondary institutions except the university have been in a state of transition from the former system of district vocational schools to a network of regional community colleges and provincial colleges of applied arts and technology. While the Cabot Institute and the Marine Institute appear to have stabilized to serve their intended functions, other institutions have remained in a state of flux. The mandates of the community colleges are clearly much broader than those of the vocational schools. The financial and administrative regimes have also changed substantially, with the appointment of local boards of directors and shifts in the manner of allocation of federal training funds.

Our concern is not with the overall structure of the community colleges. The main question to be asked here is whether, as these institutions attempt to develop their mandates, there is a role to be played in alleviating some the problems of participation in mathematics and science. There seem to be two answers to this question. The first has to do with the link between the community colleges and the university. The second involves the argument that the community colleges are ideally placed to fill gaps in other parts of the system and to overcome some of the shortcomings imposed on education by the province's geography and history.

Broadening the availability first-year courses in various parts of the province was obviously a popular stance in the recent provincial election campaign. While the specifics of what would be done varied from party to party, all seemed to agree that there is a need for wider access to university courses. One can infer that the perception of need arises from a reading of the wishes of constituents. Certainly, there has been no shortage of public statements by local advocacy groups on this matter. The basis for much of the political attention is the general problem of access to programs for those living outside of St. John's, and particularly the reduction of cost when students can continue to live at home while pursuing post-secondary studies. For our purposes, this argument is consistent with the need to attract more students to higher education, especially in mathematics and the sciences.

It is interesting to ask why the focus on university programs, when the mandate of the community colleges is essentially local, and when university courses are inherently universal in nature? One perspective on this might be that these are the most prestigious programs. Another might be that these happen to be the easiest programs to put in place (university courses are already well structured, and require less elaborate facilities than many other kinds of courses). A more positive, and more plausible, view is that university programs are seen as opening many more doors to opportunity than other programs, especially in areas where there are few identifiable local demands for technical or applied arts skills.

Looking at the issue more broadly, essentially two models for community colleges can be found in Canada. What we may call the Ontario model is one which clearly separates the function of community colleges from that of universities. Community colleges in Ontario were deliberately set up to offer an alternative to universities, and were precluded from establishing university transfer programs. Instead, these colleges have developed a wide range of applied arts and technology programs which fit well with the highly diversified industrial base of that province, and have, indeed, helped contribute to the development of that base.

The alternative is one in which the community colleges are structured to serve essentially as pre-university institutions. The purest form of this model is found in Quebec. All students wishing to enter universities in Quebec must first spend two years at a community college. While the colleges also have an applied arts and technology mandate, the university transfer programs are dominant. As for the universities, these institutions are thus largely relieved of the task of offering the first two years of the program.

The community college systems in most other provinces, especially in the West, operate in a mixed mode, with both university transfer and applied arts branches. No province other than Quebec uses the community colleges as the main entry point to university, however. Recent developments in Newfoundland suggest that a mixed model is also likely to emerge here.

The earliest major report on community colleges in this province[1] made the argument that the community colleges should be structures along the lines of the Ontario model, in order to ensure that the university transfer function did not distract these institutions from their community mandate from the beginning. Both existing developments and educational realities now appear to require that this position be reversed. If the reality of local demand is that university programs are being sought, then it seems contradictory to argue that community colleges should ignore this and pursue some other image of local demand. Furthermore, it is obvious that conditions for first year students at the St. John's campus of Memorial University have deteriorated as a result of increased enrolment pressure and shifts in the focus of attention of faculty. Finally, it is becoming increasingly clear that university programs offer the greatest opportunities for our young people, from both a career and a general education perspective.

Perhaps the most compelling argument favouring a transfer of much of the responsibility for first year courses to the community colleges is the "service" nature of many of these courses. Students take first year mathematics and science courses largely as prerequisites to entry to professional faculties and to specialized studies in areas other than the specific subjects of concern here. Furthermore, individuals hired by the university for their research potential and expertise to deal with senior and graduate programs are not being well utilized if they spend most of their time with first year courses. While there are advantages to doing some teaching at this level, the fact of the matter is that first year demands are simply overwhelming for many of the science departments.

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[1] Task Force on Education. **Improving School Retention and Post-Secondary Participation.** St. John's: Queen's Printer, 1980.

Some have argued against transferring such courses to the community colleges on the grounds that it becomes more difficult to control the content and standards of courses offered in a variety of settings. There is certainly a concern within the university on this point. An extreme counter argument to this position is that in its zeal for maintaining standards, the university, and particularly the Mathematics Department, has lost sight of the transition problems of students and has been content to simply allow large numbers to fail. Indeed, some have gone as far as to argue that the university has deliberately kept the failure rate in mathematics high in order to screen candidates to avoid excess demand at the senior levels, particularly in the professional faculties. It has also been alleged by some that the university accepts large numbers of students in order to maintain its financial base or the jobs of faculty members.

It is not clear where the truth lies in these arguments. In our estimation, none of the extreme positions can be sustained. What can be defended is an argument that the university is not the best place to teach courses whose primary function is service to other entities rather than specialization within the subject itself. Aside from arguments over whether professors are concerned with the problems of first year students, it is clear that the university is an inefficient place to deal with large numbers of students in transition, because teaching loads are traditionally small and because staff hired primarily for their research potential are not well employed in dealing with such students. Fortunately, at Memorial, many of those now teaching first year courses were originally appointed to the former Junior Division, and retain a primary interest in first year teaching. This cannot be expected to continue, however, as hiring priorities have undergone a drastic shift as the university attempts to develop a reputation as a research institution.

On balance, participation rates in first year courses, as well as the quality of teaching in such courses, can be enhanced by a shift of much of the burden of such courses away from the main campus of Memorial University and into the community colleges. Any concerns with standards caused by such a move can be addressed through collaboration on course content and through specific examination procedures, as outlined in a subsequent chapter. Our general recommendation is therefore:

Recommendation 8.3

That the regional community colleges be given a mandate and resources to allow a full first year university program to be carried out at all centres where sufficient students can be identified to create viable classes.

Community Colleges and other Post-Secondary Programs

First year programs at other post-secondary institutions in the province differ in a number of important ways from those at the university. To begin with, these institutions have avoided excessive pressure on their programs by maintaining fairly rigid admission quotas. They have also generally identified their mathematics and science courses with specific technical programs, and have attempted to tailor these courses to the requirements of such programs. Class sizes at these institutions are quite small in comparison with the university. Substantially more time is also allocated to courses covering essentially the same material.

Nevertheless, these institutions have been unable to avoid the general decline in mathematics performance, and have been unable to successfully remediate deficiencies. It has already been argued that this further supports the view that many of the difficulties stem from the high school program. At the same time, it is necessary to point out that less than half the students in many of the programs in these institutions come directly from high school. Such students can be expected to require different treatment from their younger counterparts.

The problem at these institutions has also been compounded by high attrition rates, leading to some programs being under subscribed beyond the first year. A further characteristic of these institutions, as already pointed out, is the inability of students to change programs if an inappropriate initial choice is made, as is common in the university setting. From the point of view of participation, therefore, the problems of the non-university institutions, though different, seem to be no less serious. Of particular concern is the practice of admitting students on the basis of capacity in the first year, knowing that this will lead to the institutions operating below capacity in classes later in the program.

An examination of the mathematics and science courses at the Cabot and Marine Institutes indicates that the courses for different programs, particularly those in the same general area, such as the engineering technologies, almost completely overlap in content. While they may differ somewhat in examples used, these differences do not appear to be sufficient to justify separate courses. Certainly university students exposed to a common first year course are expected to move to a wide variety of areas of applied mathematics and science. In any case, given the uncertainty in the ultimate destinations of students, it difficult to make a case for specialization of mathematics and science courses in the first year.

Some might argue that the demand for "relevance" in programs requires that courses become specialized as soon as possible. However, we must recognize that the goals of mathematics and science teaching extend well beyond the immediate demands of the area of specialization towards which a student is headed. A stronger argument can be made that the first year of post-secondary education, whether in universities or other colleges of applied arts and technology, should be a time of liberal education. In particular, this should be a time to consolidate and further develop the citizenship, literacy, and critical thinking goals of mathematics and science education.

All things considered, it seems appropriate for the post-secondary institutions to work towards a more common first year program, which would contribute to the broad goals of mathematics and science education, as well as increasing flexibility in subsequent choice of programs and institutions. Such a move would also have distinct administrative advantages, in optimizing the use of facilities, staff, and resources throughout the system. This, in fact, leads to the argument that the community college system is the appropriate place to carry out these programs. What is being argued for, in fact is an extension of the idea of offering first year university courses to the development of a generic first year program which would allow advanced standing on entry to either the university or the other provincial institutions.

Recommendation 8.4

That the Department of Education convene a working group, with representation from Memorial University, the provincial institutes of applied arts and technology, and the community colleges, to develop a generic first year program, to be offered by the community colleges, which would permit entrance with advanced standing to any of the provincial post-secondary institutions.

Recommendation 8.5

That the community college program be considered the normal route for entrance to the provincial institutions, and that the latter institutions scale down their first year programs accordingly.

Recommendation 8.6

That the provincial institutions use the resources freed by the scaling down of first year courses to increase their capacity in programs beyond the first year.

Community Colleges and Remediation

The post-secondary institutions in the province have had a long history of providing remedial services for those who lack the basic requirements for entrance to their mainstream programs. The most obvious example of this was the Junior Division at Memorial University, which was established in the late 1960s out of a sense that many high schools were at that time fundamentally incapable of offering programs which could meet university expectations. In fact, it is somewhat ironic that, having disbanded the Junior Division, the university continues to have much the same concerns as when that division was established. The main difference is that it is now perceived that the high schools should be able to do what the Junior Division was expected to do two decades ago. The other post-secondary institutions, along with the district vocational schools, have had a long history of adult upgrading, under various federally funded programs. Other routes, including adult education programs and the high school equivalency examination (GED) offered by the Department of Education, are also available to students wishing to upgrade to the high school graduation level.

No matter what changes are made in the system, there is likely to remain a substantial need for programs which will allow students to upgrade to meet entrance requirements for post-secondary programs, and, more important, to succeed in these programs. Individuals will continue to come to post-secondary programs by a variety of routes, at varying ages, and from different school experiences. This indicates that there is likely to be a continuing need for remedial programs of various sorts, if we are to increase participation rates.

Again, the point may be made that the post-secondary institutions, particularly the university, are not the most suitable places to accommodate such variation. In fact, in disbanding the Junior Division, the university seems to have deliberately abandoned a remedial role. In the other institutions, adult upgrading has been separate from post-secondary programs, in the sense that students are not accepted into these programs and then placed on a remedial track. Instructors in post-secondary institutions are employed for their specialized capabilities, not for their skill in treating special student problems. Nor are the institutions funded with such problems in mind. These institutions must meet accepted national and international standards in their programs, and must produce graduates who can function in a world market. To return to the idea of a Junior Division or some other form of deliberate remedial role would distract from their essential missions.

Our specific concern here is with students who might be excluded from post-secondary programs once the revised mathematics program is implemented, or with those who, for various other reasons, have been unable to meet the more rigorous achievement criteria which must be imposed in the schools. This, again, is where the community colleges have a role. The community colleges are not subject to the same constraints as the university and technical institutes. In fact, their essential role is to operate in a local context, and to meet the specific demands of the community in which they function. Adult upgrading, and other forms of remediation, are quite appropriate roles for community colleges to play, as long as demands for such services exist in the community. In fact, it would not be unreasonable to expect that the community colleges would fill in the gaps in high school programs, where high schools are too small to allow complete programs to be offered. Overall, it is proposed that the community colleges be the primary agents for such work.

Recommendation 8.7

That the community colleges assume responsibility for all remedial activities stemming from limitations in the ability of secondary schools to offer full programs, and from the need for student upgrading to meet post-secondary expectations.

It should be stressed that it is not intended by this recommendation that the community colleges fulfil the normal functions of high schools. It is expected, as pointed out earlier, that all high schools would offer a program suitable to admit students to post-secondary studies. The recommendation simply recognizes that there will always be students who do not succeed the first time around in high school, who will emerge from high school with various deficiencies in their backgrounds, or who will simply require refresher programs if they have been out of school for some time. Rather than simply letting such students cope with regular programs as best they can, or giving the responsibility to provincial institutions which are ill-prepared for the role, the community colleges are seen as natural settings for remediation.

Provisions for Exceptional Students

In an educational system built on egalitarian ideals, and especially one which has had to struggle to meet even basic program needs, it is not surprising that few special provisions have been made for students who show exceptional academic talent. In many ways, the structure of education has been opposite to that found in industry, sports, music, or other areas in which competition and the encouragement of exceptional abilities are taken as the norm. Some school boards have begun to recognize this as a gap, and have begun to mount so-called "gifted" programs. Such programs are typically considered part of special education, and represent an expansion of the thinking in this area, since typically it is only students with handicaps of various sorts who have been placed in this category. Our concern is with whether there should be special provisions for students who excel in mathematics and science. More specifically, the idea is to use such programs as a vehicle for attracting more of the most talented students to mathematics and science programs.

Looking at other educational systems, a number of models for special programs can be identified. The most straightforward of these is simply providing for increased specialization in mathematics and science within regular school programs. Schools in Britain, for example, typically allow students to select areas of specialization early in their high school careers. In large urban areas, "magnet schools" have been established, which attract students interested in specific subjects. In some areas, of course, it is possible for parents to choose various kinds of alternative schools, usually private, but sometimes part of the public schools system. Schools which emphasize athletics, music, dance, and the like are not uncommon throughout the world. Outside the school system, summer programs for especially talented students exist (the **Shad Valley** program is perhaps the best known in Canada). A particular version of such programs is the ubiquitous "computer camps" which have sprung up in many localities since microcomputers have become readily available.

Within the local context, some of these models would be exceedingly difficult to implement, because of the scattered distribution of students with the appropriate talents and interests, and because the private sponsorship on which some programs depend would be difficult to attract on a local scale. Nevertheless, such initiatives should be encouraged. Only two prospects seem to be reasonably feasible within the school system itself. First, larger high schools should be encouraged to offer a package of advanced courses in mathematics and science for students who wish to specialize in these areas. Existing courses in statistics, electricity, and computing are examples of what might be done. It is suggested that at least some courses be at a more advanced level than typically found in high schools, and that there be some provision for advanced credit at the post-secondary level for such courses. Introductory calculus, computer programming, electronics, biochemistry, and similar areas would be quite feasible in some schools.

Most courses of this sort could be made available only in the largest schools. For students from smaller schools, an alternative possibility is required. What is suggested is that one or more of the community colleges develop a program specifically designed to appeal to final year high school students who show exceptional promise in mathematics and science. For students from small schools, it is proposed that a modest program of financial assistance be put in place to allow such students to take these programs in larger schools or community colleges.

Recommendation 8.8

That a package of advanced courses in science and mathematics be developed, to allow greater specialization by students who show exceptional promise in these areas.

Recommendation 8.9

That the community colleges offer, on an experimental basis, a specialized program in science and mathematics specifically for grade 12 students from small schools, and that a program of scholarships and other financial assistance be made available on a sufficient scale to allow at least one class in this program to function in the province each year.

Scholarships

This last point leads us to what is obviously the most direct way to encourage participation in areas of strategic importance. Scholarships have been traditionally used as a tool to attract the best students to particular institutions or programs. Although providing scholarships involves direct costs, a strong argument can be made that this is one of the least expensive ways of improving participation, since the funds are directly targeted, and are contingent upon maintaining high levels of performance.

Within the sciences, this has recently been recognized by the federal government, in its recent implementation of a national scholarships program (The Canada Scholarships Program). This program provides 2500 new scholarships per year to students entering university undergraduate programs in science and mathematics. These scholarships have a value of $2000 for each year of the undergraduate program. The scholarships are restricted to those enroled in the basic sciences and mathematics. Those entering professional faculties such as medicine, engineering, or teaching are ineligible.

Under the current system of quotas for institutions, 44 of these scholarships were awarded to students at Memorial University in 1988. This is close to what would be expected on a per-capita basis. Plans have been under way to develop a single national competition for such scholarships. It is difficult to predict how well students from this province would do in such a competition. The comparative achievement data suggest that in any competition based on achievement testing our students are likely to be at a substantial disadvantage. Some have argued, in fact, that this is a reason for not moving to a national competition. It is more in the spirit of this report, however, to argue that this problem should be avoided by improving achievement, not by having separate provincial competitions or using other devices to avoid exposing what might be embarrassingly low performance.

At the provincial level, students graduating from high school are eligible for two kinds of provincial scholarships; the Electoral District Scholarships and the Centenary of Responsible Government

Scholarships. Fifty-two of the first and 55 of the second are available. These scholarships have a value of $ 600 each, an amount which has not been increased since the 1950s. In addition, a single Junior Jubilee scholarship, valued at $ 1000 is available. Students in attendance at Memorial University are also eligible for several other provincial scholarships, as well as a variety of university and privately funded scholarships. However, virtually none of these scholarships have had their values increased in recent years, and none are of a value comparable to the Canada Scholarships already mentioned.

We have not been able to carry out a complete assessment of scholarship programs available to students across the country. However, it is clear that the value of provincial scholarships has been seriously eroded over the past twenty years. These scholarships are in no sense competitive with the Canada Scholarships program. In any case, none of these scholarships are targeted towards areas of strategic importance. There are two main advantages of such targeted scholarships for science and mathematics. First, they represent a direct approach to increasing participation. Funds are spent only on students who are likely to pursue careers in the area. Second, they help ensure that the best students are attracted towards the field. Scholarships which are tenable for several years are especially valuable because they give students strong incentives to remain in the designated programs and to perform well. This is essentially the approach taken in the federal program.

The Task Force believes that a provincial program designed to complement the Canada Scholarships in mathematics and science would be an important step in improving the profile of these areas, and in increasing participation rates. A provincial program should cover certain areas excluded from the federal program, and should specifically include mathematics and science teaching, engineering, nursing, and selected other professional fields. It is therefore recommmended:

Recommendation 8.10

That the provincial government establish a program of scholarships in mathematics and science, on a scale comparable to the Canada Scholarships Program, and that students in designated professional fields such as teaching, engineering, and nursing, as well as those in the pure science disciplines, be eligible for such scholarships.

Participation of Women

The data on participation in mathematics and science programs show that there continues to be substantial imbalance in the participation rates of male and female students. At the high school level the imbalance is fairly small, favouring boys in physics and environmental science. Numbers are almost equally balanced in both the advanced and academic mathematics courses. However, boys slightly outnumber girls in the basic mathematics courses.

Much wider discrepancies occur at the post-secondary level, especially in non-university programs. For example, the engineering technologies are almost exclusively male, while programs in medical technology are largely female. Only the accounting programs show a reasonably balanced representation. Among university programs, engineering remains almost exclusively a male faculty, while nursing is equally exclusively female. A major turnaround has occurred in medicine in recent years, with that faculty now attracting a reasonably well balanced representation of males and females. Among the science disciplines themselves, all areas except biology and biochemistry are male dominated. While male/female ratios do vary from year to year, there appears to be no clear trend towards greater balance in recent years.

This is not the place to review all of the documentation on sex role stereotyping and discrimination against women. Suffice it to say that the Task Force supports the thrust of submissions made on this matter, which call for the removal of stereotyping in texts, presentation of positive role models for women, improved guidance programs and the like. However, one gets a sense that more is required. Under current circumstances, it will take some time before there are sufficient female engineers or physicists to create the necessary visible role models, especially in rural areas. Even high school mathematics and science teaching remain largely male dominated. The only promising area for role model development seems to be medicine.

This raises the question of whether more drastic action such as the imposition of quotas in various fields should be considered. Surprisingly, none of the submissions from women's advocacy groups went as far as to recommend quotas. Some believe that quotas have been applied in medicine. However, as far as we have been able to determine, the change in medicine has come about because the Faculty of Medicine has been receiving large numbers of applications from highly qualified women. Quotas or other forms of affirmative action have not been required.

On balance, quotas in specific fields such as engineering (or nursing, at the opposite extreme) seem neither desirable nor feasible. One place where it does seem reasonable to argue for quotas is in new programs which might be put in place specifically to encourage participation. In the current context, these are confined to the proposed special school and community college courses, and the proposed scholarship program. The following recommendation specifically addresses this point:

Recommendation 8.11

That any new program designed to encourage participation in mathematics and science be designed to ensure equal participation of men and women. Specifically, half of all scholarships in mathematics and science and half of all places in special school programs for talented students should normally go to women.

The last recommendation in this section is intended to make clear that the Task Force endorses all attempts to increase awareness of post-secondary and career opportunities for women, and encourages high schools to pay explicit attention to this issue.

Recommendation 8.12

That high school teachers, administrators, and guidance personnel ensure that all possible efforts are made to avoid sex discrimination or stereotyping in course selection, career guidance, recruitment programs, and similar activities, and that they take positive steps at every opportunity to encourage young women to choose non-traditional science based post-secondary programs and careers.

CHAPTER 9

SCIENCE AND MATHEMATICS CURRICULUM

The curriculum is the vehicle through which the aims of education are supposed to be carried out. To most people, the school curriculum is represented by course descriptions, textbooks, teaching guides, and similar materials. Such materials are typically developed by the appropriate educational jurisdiction, and are prescribed for teacher and student use. In this province, as in most others in Canada, curriculum has traditionally been the responsibility of the Department of Education. Documents prepared (or selected) by the Department are therefore the appropriate ones to examine in analyzing the curriculum.

At the post-secondary level, responsibility for curriculum is less clearly defined. In universities, the academic departments are generally considered the appropriate units to decide on curriculum. In some other post-secondary institutions, the curriculum may be determined by external considerations, such as the requirements of national accrediting bodies. What is clear is that post-secondary curriculum is not prescribed by the province, as is the case for curriculum at other levels.

The level of curriculum represented by official statements, textbooks and the like is commonly referred to as the intended or mandated curriculum. However, curriculum may also be said to exist at a second level, sometimes called the translated curriculum. This level exists because it is obvious that school districts, schools, and teachers place their own interpretations on the intended curriculum. What it actually taught may therefore not be the same as what is intended. It is at this level that many curricular difficulties occur, because there can be no assurance that the intended curriculum will be interpreted and used in a uniform way. The literature on curriculum implementation gives many examples of how teacher interpretations are of crucial importance. In any analysis of curriculum, therefore, it is necessary to allow for variations in interpretation, and to assess the impact of such variations.

This chapter focuses on the intended curriculum. It begins with an overview of basic curriculum structures in the schools of this province. A brief analysis is given of mathematics and science programs at the various levels of the system. Data on how our curriculum in mathematics and science compares with programs elsewhere are then examined. Finally, a set of general principles underlying mathematics and science curriculum are outlined, and recommendations made on needed changes in curriculum.

The analysis is restricted to curriculum in the regular school system. Beyond comparative analysis of first year university courses, it was not possible to examine in detail individual courses at the post-secondary level. Our sense is that the post-secondary curriculum is constrained by external demands, and is designed largely to parallel similar programs elsewhere. We would observe only that any attempt to develop generic first year programs, as proposed earlier, should take into account the need for continued attention to the broad objectives of mathematics and science teaching, and that the focus should not become too narrowly focused at that stage towards the demands of the next stages of student programs.

Overview

It must be recognized from the outset that curriculum in this province is highly centralized. The Department of Education is responsible for determining the overall structure of the curriculum and for preparing and selecting the basic curriculum documents. Course outlines, teaching guides, and similar materials are considered prescriptive. The status of textbooks is less clear, although for the most part, textbooks are treated as prescribed.

It is conventional to refer to four basic levels of schooling in the province. These are Primary (grades K-3), elementary (grades 4-6), Intermediate or Junior High (grades 7-9), and Senior High (grades 10-12). While not all schools are organized specifically along these lines, this is the basis for curriculum development and implementation. At the senior high school level, courses are referred to as level I, II, or III in terms of sequence and credit requirements. In fact, the use of conventional grade designations has largely disappeared within the high schools. Throughout this chapter, we shall refer to specific courses as being level I, [illegible]r III, but will retain the conventional grade designations when referring to overall school organization.

A common core curriculum may be said to exist at the primary, elementary, and intermediate levels (through the end of grade 9). That is, it is expected that all schools will offer the same basic program. Nevertheless, there may be substantial variation in emphasis on different parts of the curriculum, depending on choices made by districts, schools, and teachers. Programs are often limited by the availability of facilities and teachers. Furthermore, since the central authority makes no attempt to determine whether schools are conforming to the prescribed curriculum, there is considerable scope for the exercise of discretion on course content, time allocations, and other elements, which can contribute to a large difference between intended and translated curriculums.

At the senior high school level, a deliberate attempt is made at curriculum differentiation. This is accomplished through a credit system, and by the existence of a wide variety of courses. Although there are certain core requirements, it is possible for students to graduate from high school having taken widely different patterns of courses. In principle, such differentiation is designed to allow students to choose programs in accordance with their needs and interests. In practice, however, such choice is often limited by the capacity of schools to offer particular courses, by requirements imposed at the district and school level, and by post-secondary admission requirements.

The intermediate and senior high school programs require further comment. At the senior level, the introduction of grade 12 a few years ago was accompanied by a large scale revision of the curriculum. This revision has been often cited as the main reason for poor performance in mathematics and science. Several features of the revised program are particularly relevant to our analysis. A similar revision is now being planned for the intermediate level. Each these developments is discussed briefly in the following sections.

Intermediate Program

For the past several years, the Department of Education has been working towards a major revision of the intermediate program. Draft reports have been prepared, and reaction sought from various interest groups within the system. Although a final draft report is now ready, the status of the revision is not completely clear. Some schools seem to have received a message that the basic features of the program are in place. Others assume that the program will come into effect next year. The position of the Department of Education is that plans for implementation are proceeding but that no final decision has yet been made on timing. The Department, however, remains committed to the revision.

Plans for revision of the intermediate program have their fundamental grounding in a consideration of the nature of adolescence. The most obvious manifestation of this is the adoption of the principle that most teaching at this level should be done within a homeroom setting, rather than by specialist teachers. A second major feature is a broadening of the program, to include certain courses such as industrial arts as requirements. Finally, time allocations have been restructured, both to allow room for new courses and to give some flexibility for schools to emphasize remediation or enrichment in particular areas.

The revision, in itself, has implications for the content of mathematics and science programs, since it is clear that time for these subjects is likely to be restricted by the increased demands in other areas. Furthermore, the principle of homeroom teaching is seen by many as being highly detrimental to these programs. In the extreme, it is argued that core subjects are being sacrificed to peripheral areas. Many have also made the point that the treatment of mathematics and science as homeroom subjects is based on the false assumption that most teachers are adequately prepared to teach these subjects. These points will be taken up in more detail in the chapter on instruction.

On a broader, level, the history of this program provides a classic case in point to illustrate the glacial pace of curriculum development in the province, and the obstacles which exist to any major innovation. The current revision originated with a committee which began its work in 1981. The first main draft of the report was produced in 1985. Since that time, schools have been expecting some definitive statement on implementation. We now learn, in early 1989, that no firm decision has yet been made. The major obstacles to implementation are now cost and teacher upgrading. In particular, some of the new requirements, such as industrial arts, have substantial capital and operating costs attached. This ties the program to broader issues of school tax equalization and increases in operational funding. Overall, it appears as if the Department of Education is trying to accomplish the impossible in such an ambitious revision. It is therefore recommended:

Recommendation 9.1

That the proposed revised intermediate school program NOT be implemented in its present form, and that the program be reformulated to allow stronger emphasis on core subjects, particularly mathematics and science.

Senior High School Program

The basis for the revised high school program was the perceived need to broaden the curriculum to accommodate the needs, interests, and abilities of a larger variety of students. The additional year of schooling was introduced essentially as a means of acquiring the extra time necessary to accommodate this added breadth. Although not stated as explicit objectives, it is clear that reducing failure and dropout rates were important underlying goals. The basic academic courses which formed the core of the previous program were not the main targets of revision. Although there were substantial changes in other subjects, the content of science and mathematics courses remained essentially untouched. Most of the additional time was taken up by increased requirements in language and social studies. The specific science and mathematics requirements for graduation were, in fact, reduced substantially. Nevertheless, in practice most students select courses beyond the minimum requirements, and enrolments in certain science areas, in particular, have increased.

A single credit in the high school program is considered to be equivalent to 55-60 hours of instruction. Most courses carry two credits, which usually amounts to one class period per day over the school year. Students are required to complete a total of 36 credits for high school graduation. Of these, a total of 21 credits are considered as meeting core requirements. Two specific courses, Cultural Heritage 1200 and Democracy 2102 are required of all students. Other core credits must be selected as follows:

- 3 in English Language
- 2 in Mathematics
- 4 in English Literature
- 2 in Science
- 2 in World Study

- 4 from each of two of the following:
    - Religious Education
    - Physical Education/Health
    - Music/Art/Performing Arts
    - Family Studies
    - French

School districts frequently impose certain requirements in addition to those listed. Religious Education and Physical Education, for example, are normally made part of the requirements for graduation.

High School Mathematics and Science Requirements

It is clear from the above listing that the basic requirements in mathematics and science are quite minimal. A student can graduate from high school with only two credits in each of science and mathematics. It is somewhat reassuring to note that, in practice, most students take more than this minimum. Nevertheless, the minimum requirement may be seen as a statement of the low priority assigned to these subjects in the overall program structure. This priority is clearly not in accord with the reality of the world and the wishes of students, the public, and post-secondary institutions. The arguments already made lead to a need to state quite unequivocally that the minimum requirement in the current program needs to be substantially increased.

Recommendation 9.2

That the minimum requirement for high school graduation in both science and mathematics be increased from two to six credits.

Some might argue that this recommendation would place a great deal of pressure on the program, and could be implemented only at the expense of other important courses. Two points may be made in response to this argument. First, numerous submissions to the Task Force made the point that some of the existing required courses have little substance and could easily be eliminated, consolidated, or made elective. More important, it has become almost universal practice for schools to require students to complete 42 instead of 36 credits over three years. This is done for the simple reason that the timetable consists of seven periods per day over a six day cycle in almost all schools. This fits exactly the requirements for 14 credits but would allow students free time if only 12 were taken.

School officials generally assume that a student's timetable must be completely filled. If we accept this assumption, then there is substantial scope to add requirements to the program. In fact, the current structure allows students to complete most of their required courses in the first two years in many schools, leaving grade 12 as a rather relaxed year. Some have gone as far as to argue that the poor habits learned during the grade 12 year contribute to poor performance in post-secondary programs. Even if this is not the case, there is little doubt that there is some slack in the current program.

Of course, a statement about course structures and credits tells us nothing about the content of the program. It is therefore necessary to examine in some detail the programs now in place, and to ask whether these are consistent with the goals already outlined. It is also necessary to look at the process of curriculum development in the province, to determine whether the appropriate means have been developed to ensure that high quality science and mathematics programs are being implemented and that such programs are continually under review.

Mathematics Curriculum

Primary. A new mathematics program was introduced in grades 1-3 in September, 1988. In keeping with standards for mathematics instruction prepared by the National Council of Teachers of Mathematics (NCTM),[1] the curriculum treats problem-solving as the primary objective of mathematics teaching. Other more conventional objectives (numeration, geometry, measurement) are also developed. Finally, graphing is treated as a separate main objective, in keeping with the notion that data handling is an increasingly important skill. A notable feature of the program is the emphasis on the use of concrete materials and, in particular, the supply of the appropriate materials to all classrooms. This policy of providing non-print materials represents a substantial departure from the practice in most curriculum areas, where it is assumed that schools are responsible for providing such supplies.

In practice, the program revolves around a commercial textbook series, **MathQuest**, published by Addison Wesley. The essential difference between this and other programs, however, is the explicit statement that the curriculum guide takes precedence over the textbook. Our inquiries lead us to believe, however, that the guide is still seen as something to be dusted off occasionally for general reference, while the textbook remains the primary day to day tool.

The relationship between the curriculum guide and the textbook content is by no means straightforward. The complexity is illustrated by the attempt in the guide to match textbook pages with particular objectives. No teacher could be expected to cover a textbook in such a fragmented fashion. This relationship is but one instance of a general problem of lack of congruence between objectives and content. It is perfectly possible, for example, to proceed through the entire program without ever asking whether what is being done is contributing to the development of problem-solving skills. Although the quality of the guide represents a substantial improvement over most such documents prepared by the Department of Education, textbooks remain far superior documents in terms of print quality, layout, convenience of use and similar features. It is therefore not at all surprising that the text is the preferred document.

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[1] National Council of Teachers of Mathematics. **Curriculum and Evaluation Standards for School Mathematics.** Reston, Virginia: NCTM., 1979.

Elementary. Little needs to be said about the elementary mathematics program. As the program currently in use (**Investigating School Mathematics**, also by Addison Wesley) is to be replaced over the next couple of years by the continuation of the MathQuest program, there is little point in commenting on the older program. The only important point to make is that a way must be found to develop a more direct linkage between the curriculum guide and the textbook. This is where a more sophisticated curriculum development process is required. Unless we are to assume that textbook publishers can do a better job of deciding our objectives than our own curriculum developers, then the publishers should be required to organize their texts around our objectives rather than the other way around.

Intermediate. The current intermediate mathematics program has been in place for more than a decade. The program is based on the **Math Is** text series published by Nelson Canada. A revised edition of the texts was put in place in 1984, and a draft curriculum guide was prepared. The history of this guide gives a strong illustration of some of the problems of curriculum development in the province. Authorization of the guide has been postponed for five years running, on the basis that it should be implemented in conjunction with the revised intermediate program. The draft guide has become outdated while awaiting approval because developments at the primary and elementary levels, along with the new NCTM Standards now lead to a requirement for further revision of intermediate mathematics.

Senior High School. Mathematics at the senior high school level has been at the centre of the controversy which led to this inquiry being established. A variety of issues associated with this program have already been discussed in Chapter 7. It will be recalled that the basic recommendation emerging from that discussion was that the current academic and advanced courses be replaced by a common course at a level equivalent to advanced mathematics. This recommendation was based on an analysis of achievement levels and selection factors in the two courses. At this point, the recommendation can be reinforced by a comparative analysis of programs in other provinces, based on studies commissioned by the Task Force.

A detailed account of senior secondary mathematics and science programs across Canada is given in **Background Report #4.** This account is supplemented by an analysis of the content of public examinations in Alberta and British Columbia which appears in **Background Report #6.** Briefly, the analysis bears out the point that the main course for post-secondary admission in most other provinces is closer to our advanced than to our academic mathematics. Courses that are labelled "advanced" in other provinces are usually intended for students who plan to enter university science and engineering programs, and carry some form of advanced credit for university entrance. Such courses typically include introductory calculus. Students from this province are thus at a clear disadvantage in admission to out-of-province universities. As has already been argued, it has also been necessary for Memorial University to offer a pre-calculus algebra course as the normal first level course, instead of moving directly to calculus, as is generally the case across the country.

The sequence of courses commonly referred to as "basic mathematics" consists of two credit courses in consumer, vocational, and business mathematics. These courses present few problems in themselves. In fact, a good argument can be made that such courses would be useful for all students, and not just for the academically weak. If there is a problem, it is an extension of the overall problem of low expectations. While some students will likely continue to require such courses to meet high school graduation requirements, the general policy should be that students should not be encouraged to substitute such courses for the more academically demanding route.

Science Curriculum

Primary/Elementary. Science has been a formal part of the primary and elementary curriculum only since the early 1970s. The earliest science curriculum guide for these levels dates from 1978. In practice, the course in place over the past decade has been based on an American commercial textbook series, now called **Addison Wesley Science**. (Its former title **Space, Time, Energy, Matter, or STEM,** was somewhat more revealing). The emphasis in this program, as the original title implies, is on basic underlying science concepts. The concept of energy, for example, is treated at various levels, from pushes and pulls in the early grades to forces and motion at the higher levels.

New curriculum guides for the primary and elementary levels have been in preparation for several years. The primary guide was authorized at the beginning of the 1988-89 school year, while the elementary guide is in final draft form, awaiting authorization. While these guides represent a substantial improvement over earlier documents, they still suffer from the serious problem of lack of congruence between broad objectives and actual curriculum content, as represented by the published textbooks. The primary guide, for example, proceeds directly from a broad statement of objectives to a detailed content outline based on the textbook series. One is hard pressed to find any connection between the objectives and the outline.

The primary guide also fails to address what seems to be the major issue in primary teaching in this province - that of the integrated curriculum. The underlying basis of the primary program is that traditional subject distinctions should be blurred, and that teaching should be done through themes which cut across subject areas. On the other hand, science is outlined as a differentiated course. While there is a column in the content outline labelled "integration", this column is almost totally devoid of clear ideas on how integration can be accomplished. More generally, the guide is ambivalent on whether or not the course **should** be integrated. Again, this illustrates how new ideas become superimposed on a curriculum, without any real integration of these ideas into what is essentially still a traditional content outline.

The elementary guide is better in a number of respects. First, it avoids giving an explicit content outline. This gives more room to discuss objectives in more detail and to give a more elaborated description of the meaning of scientific processes. The elementary guide also discusses teaching practices more clearly, provides apparatus lists, and gives various other practical teaching suggestions.

Overall, however, it is difficult to avoid the conclusion that teachers are unlikely to regard the curriculum guides as very useful documents. There is little in either guide which gives down to earth suggestions for classroom activities. The guides emphasize activities such as field trips, apparently without recognizing that in the average classroom these are at best a once or twice a year event. The textbook series is not one which encourages much active laboratory type work, and is certainly not closely linked to the objectives of the program. The guides do little to overcome these deficiencies.

Intermediate. The current intermediate science program has been in place since 1980. The most explicit focus of this program is on scientific processes, although the program also covers the typical range of subject matter found in courses at this level. The textbook series used is a Canadian series, **Searching For Structure**, published by Holt, Rinehart, & Winston. Unlike most other texts, this series clearly reflects the underlying objectives of the program. Again, a revised curriculum guide has been in preparation for several years. A draft document was prepared in 1987, but its authorization has been delayed because of the revisions to the overall intermediate program and, it seems, also because of doubts about the adequacy of the current textbook series.

Despite the overall congruence of objectives and content in this program, the draft of the revised curriculum guide provides yet another instance of how new ideas are superimposed on old content. The example is the inclusion in the guide of the goals of science teaching as outlined by the Science Council of Canada.[2] Aside from simply stating these objectives, the guide does not indicate in any way how these relate to the course content, or even to the primary goal of the course, which is to "focus on process". Under these conditions, it is not surprising to find that teachers give little more than passing reference to objectives, or to the curriculum guides themselves.

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[2] Science Council of Canada. **Science for Every Student: Educating Canadians for Tomorrow's World.** Ottawa: Supply and Services Canada, 1984.

Senior High School. Such a wide variety of courses exists at the senior high school level that it is impossible to present a course by course analysis. The discussion is therefore confined to certain broader arguments about the structure of the program. At this level, more specific reference points are available for analysis, because of the links with post-secondary programs and because comparative data from other provinces are available (**Background Report # 4).**

The first point to be made is that the basic content in the specialized academic courses (biology, chemistry, and physics) is generally quite similar to that found in other provinces. Much of this similarity is assured by the existence of common textbooks, and by the existence of at least some information sharing across provinces. Nevertheless, the curriculum and public examination analyses show that in most cases there is a small deficit in content covered, and a somewhat greater deficit in depth of treatment in our courses compared to those elsewhere. Given a full list of topics covered in Canada, for example, more of these are omitted or treated at a lower level in Newfoundland than is generally the case across the country. The main exception to this is biology, where the local course contains a broader range of required topics, and fewer options. Nevertheless, the problem of depth of treatment is apparent here as well.

As long as we are dealing with specialized academic courses, these deficits can be fairly easily overcome. Small enhancements to course content can easily be made. The main problem is not in the specialized courses, but in the need to broaden high school science to deal more explicitly with objectives other than the conventional subject matter of the specialized courses. The high school courses suffer no less than those at other levels from the gap between objectives and content. The problem is exacerbated by a public examination system which focuses almost exclusively on conventional subject matter.

In this respect, as the Science Council of Canada Study has pointed out, this province is perhaps no worse off than others. The problem of how to address broad objectives is common in all programs. If we are to make any progress in meeting the objectives of science education outlined earlier in this report, it is necessary to break free from the constraints imposed by the specialized science courses. Scientific literacy, science for citizenship, and science for critical thinking are goals for all students. In order to attain these goals, a rethinking of course content is required. In our view, the best place to begin this is at the primary/elementary level. However, the process needs to be continued through the intermediate and senior levels. Later in this chapter, some specific proposals will be made for a rethinking of the curriculum. Before doing this, however, it is necessary to look briefly at the way in which development takes place in the province, and at ways of improving this process.

The Curriculum Development Process

As already indicated, curriculum development is essentially the responsibility of the Department of Education. Formally, responsibility lies with a major division of the Department, known as the Division of Instruction. Within the Division, there is typically one individual, known as a curriculum consultant, responsible for each of the major subject areas. The consultants in mathematics and science are each responsible for all aspects of these subjects, from primary through to the senior secondary levels. Both of these individuals therefore have very large portfolios. For example, the science consultant must handle no less than twelve separate programs (including computer studies).

There are no standing committees responsible for specific courses. Instead, consultants typically rely on advisory and working groups assembled for specific purposes. Membership of working groups is drawn from teachers, school district program coordinators, and post-secondary instructors. Such groups usually focus on an area judged in need of revision. A typical working group will prepare statements of objectives, course descriptions and guides, and advise the consultant on the selection of textbooks and other materials. Working groups also oversee pilot projects designed to aid in the selection of materials.

It is important to recognize that such an arrangement does not allow much true developmental work to take place. Instead, the goal is usually to find a commercially published program which fits reasonably well within the desired framework. Often, in fact, it appears as if the starting point is the published program. This, combined with the tendency to treat the textbook as if it were the program, gives publishers substantial control over what is occurs in the schools. Commercial programs are generally developed for larger markets, so that it is not easy for local curriculum officials to influence the overall direction of programs. Although there have been some small scale efforts by publishers to adapt programs to local conditions, these often amount to no more than token efforts, designed more for marketing purposes than for meeting local objectives.

At one time, there was perhaps little choice but to accept what textbook publishers put on the market. However, with advances in publishing technology, it is now quite feasible to produce high quality texts customized for use even in small markets. Furthermore, with appropriate changes in the curriculum development process, it will become more feasible to produce text materials locally. The latter can, in fact, be aided by the emergence of a local publishing industry which is only too anxious to gain greater access to the school market. We are therefore led to a recommendation which is of general applicability in curriculum development.

Recommendation 9.3

That textbook publishers be required to adapt their programs to the objectives of the local curriculum, as a condition of approval of a particular textbook package for use in schools.

The earlier description of current mathematics and science programs has revealed a number of serious deficiencies. The first is that the reliance on commercial publications leads to inconsistencies between statements of objectives and statements of course content. The typical curriculum guide presents at the beginning a set of high minded objectives, most recently those advocated by the Science Council of Canada. However, within a couple of pages, the document moves to a content outline derived from a textbook. In most cases, it is impossible to make any link between objectives and content. The result is that it is easy for teachers to lose sight of objectives in attempting to cover the required content. This problem is particularly acute in some high school courses, where content coverage, rather than the attainment of broad objectives, is reinforced by the examination system.

A second major problem is a lack of any attempt to link the content of any program to what has gone before and what comes after. For example, the recent draft revisions of the primary and elementary science guides are quite different from each other, even from the beginning statement of objectives. One presents essentially a process approach, while the other begins with the Science Council of Canada Objectives. If there is any coherence in the program, this stems from the use of a single textbook series throughout, rather than from a consistent set of objectives.

A unique problem exists at the primary level, because the mandate of the science program is inconsistent with the overall approach taken to primary education. Specifically, as already pointed out, primary educators and teachers tend to believe that the curriculum at this level should be integrated, with no subject distinctions. On the other hand, the science and mathematics courses at this level are clearly designed as differentiated programs. In practice, mathematics is treated in a differentiated fashion in most schools. While it is argued by many teachers that science is integrated with other subjects, it is difficult to escape the impression that the result of integration is that science receives no systematic treatment at all in many classrooms.

Perhaps the most serious of all the problems is the intolerably slow pace of curriculum development efforts. As the earlier discussion has illustrated, it is not unusual for the development of a new curriculum guide to take several years, and for the product to be only a marginal improvement on the previous document. Sometimes, ideas have become dated while draft curriculum materials are under development.

Overall, it is clear that a major thrust in mathematics and science curriculum development is required. In science, in particular, nothing short of starting at the beginning and completely reworking the program throughout the system will suffice. In mathematics, a start has already been made, and the task has been facilitated by the publication of the NCTM Standards. Nevertheless, much work remains to be done, particularly at the senior high school level.

Recommendation 9.4

That a major curriculum development program be initiated in science and mathematics. The goals would be to update all existing programs, make these programs consistent with broad objectives, articulate programs across grade levels, produce more usable curriculum guides, prepare specifications for published materials, and develop implementation plans. The aim should be to complete this task within three years.

The above recommendation implies that substantial resources will have to be devoted to curriculum development. One of the realities of this process is that it costs just as much to do good curriculum work in a small system as in a large one. While we may be devoting proportionally as much effort in this province as in other provinces, a proportional effort is not adequate. To produce curriculum documents of the quality which exists in Ontario, for example, would require resources comparable to those available in that province.

As it happens, however, a large part of the problem in this province lies in how we use the available resources. Specifically, most of the personnel capable of doing the sort of curriculum work required have been assigned to school districts rather than to the Department of Education. Each school district is assigned a number of "program coordinator" positions. In most cases, science and mathematics are combined into a single position. Nevertheless, there are more than thirty people in the school districts whose job involves curriculum work at the district level. On the other hand, the Department of Education must rely on a single consultant in each of mathematics and science, to cover the entire spectrum of courses in these areas. These individuals have no assistance other than what they can obtain from voluntary committees and an occasional more formal working group. Each consultant is responsible for the full spectrum courses in the subject area. Clearly, these consultants are operating under impossible conditions.

The immediate concern here is with the inconsistency inherent in making curriculum the responsibility of the Department of Education, while assigning most of the resources available for this task to the districts. An examination of the overall role of program coordinators has led to the conclusion that most are attempting to perform an impossible task in working with individual teachers towards the improvement of instruction. There are at least two reasons why this is so. To begin with, to do an effective job of improving instruction requires intensive work at the school level. Without being assigned to an individual school, it is impossible for a coordinator to spend the necessary time. In any case, this job is strongly sensitive to the number of teachers in the system. A drastic imbalance in workload obviously results from assignment of coordinators to districts of widely different sizes. Furthermore, the responsibilities of coordinators are spread over all levels, and usually over both science and mathematics. Individual coordinators readily admit their lack of competence to cover the entire spectrum of their assignments. A common plea by coordinators to the Task Force was for separate positions for mathematics and science in each district. Rather than recommending what would amount to a doubling of the number of coordinator positions, however, an alternative approach has been taken.

Overall, our analysis suggests that one part of the coordinator's job is impossible, while the other is not done effectively because the Department of Education lacks the resources to produce adequate curriculum guidelines. Several examples were found of coordinators spending substantial amounts of time developing district policies in areas where provincial policies are clearly required. We would therefore propose that the impossible part of the job be abandoned, in favour of a different approach to inservice teacher education to be described in Chapter 12. Coordinators would then be free to concentrate on curriculum development and implementation, working more directly within their own areas of competence. To do this properly requires a major realignment of coordinator positions, so that coordinators become agents of the Department of Education rather than of the school districts. Recognizing that this will impinge strongly on current district jurisdictions, the following recommendation is nevertheless seen as crucial to improving our capacity for curriculum development.

Recommendation 9.5

That program coordinators be reassigned from school district to Department of Education jurisdiction, and that their responsibilities be redefined specifically to include curriculum development and implementation.

Once this reassignment has been accomplished, the Department of Education will have at its disposal a formidable pool of talent for curriculum development work. Rather than relying on volunteer committees to think through curriculum objectives, research sources, write curriculum guides, and perform the other essential tasks in good curriculum development, it would be possible to assign staff on a full-time basis to these jobs. Such individuals would also be available to coordinate pilot projects, monitor implementation, and keep track of ongoing developments in the field. At the high school level, a further important task would be to assist with proposed developments in the public examinations.

There is no question of the competence of the current corps of coordinators to do these things, within their own areas of specialization. The only issue is the ability to bring these talents to bear on a particular set of tasks. While the action proposed in the recommendation might seem drastic to some, there seems to be little point in continuing to do an inadequate job, or in allocating further resources, when the basic means of improving the situation are at hand.

A comment is necessary about curriculum implementation. Many recent analyses have shown that there are often substantial variations in interpretation between those responsible for developing a program and those responsible for its implementation. Often what is seen is a sort of nominal implementation, in which textbooks and other materials are put in place but where more fundamental principles underlying the innovation become subverted as teachers attempt to merge new ideas with an entrenched body of existing practices.

The implementation model used in this province over the past decade or so has been one in which the Department of Education has worked only indirectly with teachers, through the district program coordinators. The latter group is expected to carry out most of the inservice teacher education work, and to see that programs are being properly implemented. The evidence available from teachers themselves strongly indicates that this model has not worked well. The general feeling among teachers seems to be that they have not been adequately prepared to meet the requirements of new programs. Our own analysis of curriculum guides and of the role of coordinators tends to support the view that the implementation model is inadequate.

A solution to this problem has several components. Clearly, curriculum guides need to convey an adequate picture of the goals of a program and of how these goals should be reached. The proposal to make coordinators agents of the Department of Education is also designed to provide for more accountability to the Department on what is happening to a curriculum in the field. However, the main requirement is for a major rethinking of inservice teacher education, and its particular links with curriculum change. This issue is the focal point for a full discussion of teacher education in a subsequent chapter. For the present, a general recommendation on curriculum implementation is required.

Recommendation 9.6

That the Department of Education develop a curriculum implementation model based on the principle of direct accountability to the Department, and involving the following specific elements:

- **publication of adequate curriculum guides**
- **use of program coordinators as direct agents of the Department**
- **more intensive inservice teacher education activity**

Curriculum Principles

It is useful at this point to reiterate the main principles which should underlie the redevelopment of mathematics and science curriculum in the province, and to formulate specific recommendations on the adoption of these principles as the basis for curriculum development.

The foundation for mathematics and science curriculum is found in the broad goals outlined in Chapter 3. These goals relate to literacy, citizenship, work, further education, and critical thinking. Specific variations on these goals exist for science and mathematics. In particular, a detailed set of standards for mathematics curriculum has just recently been published by the National Council of Teachers of Mathematics. While no similar standards exist for science, it has been argued earlier that the science curriculum should be built around understanding the natural world, the world of technology, and the relationship of science to society. The following recommendations are intended to reinforce these underlying ideas:

Recommendation 9.7

That the goals of literacy, citizenship, further education, work, and critical thinking/problem solving be adopted explicitly for use throughout the science and mathematics curriculum in the province, at all levels.

Recommendation 9.8

That the standards published by the National Council of Teachers of Mathematics be used as the basis for all further mathematics curriculum development in the province.

Recommendation 9.9

That science curriculum be developed around the themes of understanding the natural world, the world of technology, and the relationship between science and society.

It should again be stressed that in translating such goals into curriculum materials and classroom activities, it is necessary to go well beyond what in currently being done in the curriculum guides. Simply stating the goals at the beginning of all guides, and then proceeding with detailed course descriptions as if these goals were obvious (or worse, that they do not exist) is a prescription for curriculum failure. It is far too much to expect that teachers and students will make the necessary connections between goals and activities as a matter of course. The major challenge for the curriculum development effort proposed, is to make concrete the connection between high minded goals and the minutiae of day to day work in the classroom.

Specific Curriculum Issues

As already indicated, it is not possible in a report of this sort to give a specific critique and provide recommendations on every possible course in the mathematics and science program. Nevertheless, there are two areas which seem to be in more urgent need of attention than others, and for which the directions are not immediately obvious from the overall goals. The first of these areas is computer studies. The second concerns the need for explicit attention to the science-technology-society relationship.

Computer Studies. Currently, the only formal computer studies course in the school program is a course called Computer Studies 2206, which is an elective science course in the high school program. The course has been highly popular, attracting more than 4000 students per year. Some schools have also offered computer studies as an option at the intermediate level. In practice, a fairly wide mix of computer related activities can be found in the schools, depending on the interests and capabilities of teachers and the equipment available. The major problem is the absence of a clear sense of purpose in teaching computer studies, and the lack of appropriate curriculum guidelines and materials.

A committee report on computer use in schools has been in the hands of the Department of Education for some time, and there is substantial frustration in the field that there has been no action on this report. The computer studies area is one of many assigned to the provincial science consultant, and represents another example of how the current setup in the department makes it almost impossible to proceed with any speed on any area of curriculum development. The problem is much more complex in computing than in other areas because of the cost and rapid obsolescence of equipment, and because issues other than curriculum content, such as the use of computers as teaching tools, are at stake.

The computer studies course has drawn criticism from many quarters. Much of the criticism stems from problems of facilities, a point which is addressed in Chapter 13. The more substantive criticism, however, is that the course takes a very narrow approach to computing, specifically programming in the BASIC language, when a much broader range of issues surrounds computers and their function in society. In our view, this criticism is quite justified. Perhaps more than any other area, computing is an obvious example of how technology influences our society, and thus is a natural area in which to explore issues of literacy and citizenship, as well as those of work. More important, the computer is clearly the most powerful problem solving tool, other than the human brain, available to society. In short, there is no better area than computer studies to address directly the full range of objectives of science and mathematics teaching.

Aside from this broad purpose, a consensus seems to be developing that the primary purpose of computer studies in schools should not be to teach programming, but rather to give students some exposure to applications programs. The real world of day to day computer use in the workplace and other settings consists of word processing, data base management, spreadsheet applications, graphics, statistical analysis, and a host of similar practical applications, using prepackaged software. It is fair to predict that almost all students will encounter such applications very soon after leaving school, whether in post-secondary education or in the workplace. What students need is a sense of the power of such applications and of their universal usefulness.

To illustrate this point, even a task as simple as typing is now far different from what it was even a few years ago. To begin with, the demand for skill in typing in now much more extensive. While much higher skill levels are required to operate word processing equipment than ordinary typewriters, these skills are also more widely used by individuals other than clerical staff. Such staff are being displaced in organizations in favour of support staff possessing a much broader range of computer related skills. Those who cannot deal with such changes are at serious risk in the workplace. The schools themselves must learn to deal with the fact that many students are learning about and using computers at home, or in other settings. It is not uncommon for students' knowledge of computers to surpass that of their teachers.

This analysis could continue at length. However, what has been said is sufficient to illustrate the point that we confront a major curriculum development task in attempting to deal with the pervasive influence of the computer. This task must be pursued with all possible urgency. As a general guide to what should be done, the following recommendations are offered:

Recommendation 9.10

That the development of a computer studies program be assigned the highest priority among the curriculum development activities to be pursued.

Recommendation 9.11

That the computer studies program be based on the following general principles:

- **Early introduction to computers**
- **Inclusion of computer studies in the school program for all students**
- **Computers as the primary current illustration of the impact of technology on society**
- **Exposing students to common computer applications such as word processing, data management, graphics, and statistical analysis.**

Science-Technology-Society (STS). As we have been arguing, the broad goals of mathematics and science education are clearly intended to make clear the powerful influence of science and technology on our society, the need for all students to understand the nature of this influence. One would expect from this that the **STS** concept would become a unifying theme flowing through all courses in these areas. However, this is an ideal which will be difficult to achieve in even the best curriculum, as long as it is necessary to deal with specific details of subject matter. We must acknowledge that it is likely to be impossible to keep this theme at the forefront of primary mathematics, high school physics, or other specific courses.

This leads to the need for some means of paying explicit attention to the **STS** theme. Looking across the science curriculum, the only place in which this theme is addressed directly is in Environmental Science 3205 course, with some peripheral attention being given in Biology 3201. In the mathematics program, the theme is avoided everywhere except in the basic mathematics courses at the high school level. It may be a measure of the importance now attached to the theme that it appears primarily in courses designed for less able students. This is not a situation which should continue. All students should be exposed to a program which pays specific attention to the **STS** concept.

After examining several alternatives, and looking at existing courses in other jurisdictions, the Task Force has concluded that the most reasonable way to accomplish this would be to introduce a common course in the first year of the high school program which has this as its primary focal point. There are a number of advantages in placing the course at this level. First, this would create the least disruption of existing course sequences. For example, most intermediate programs are designed as a three year sequence, fitting the current grade structure of the intermediate school. The current specialized courses at the high school level are most suitable for grades 11 and 12 in any case. The current practice of allowing such courses to be taken in any sequence, beginning as early as grade 10 is unusual, and causes substantial difficulty in the content sequence of such courses. The main reason this is now allowed is to facilitate scheduling, especially in small schools. It is expected that this will become less of a problem as the timetable becomes less fragmented. Finally, and most important, such a course provides an opportunity to upgrade the offerings for less able students and for further reducing the amount of ability grouping which occurs in schools. It is envisaged that this course would replace the current General Science 1200, and perhaps Environmental Science 3205.

Recommendation 9.12

That a course based on the Science-Technology-Society theme be developed, and that this course be required of all students in their first year of senior high school.

CHAPTER 10

TIME ALLOCATION AND USE

Research conducted over the past couple of decades strongly supports the common sense notion that time is an important variable in school learning. In general, learning increases as more time is made available and as that time is better used. It is also widely accepted that variations in underlying student abilities and backgrounds can be reduced by appropriate time allocation and use. The concept of mastery learning, for example, is based on the premise that students of widely different abilities or levels of previous achievement can be brought to a common high level of learning by allocating more time to those who need it most.

In this chapter, time is examined from several different points of view, as indicated by the following questions:

1. How important is time as an instructional variable?

2. Is the total amount of time available at various levels of the system adequate to meet the demands being placed on the system?

3. Is there a significant amount of lost or wasted time in the system, and can any such losses be recovered?

4. Do mathematics and science receive an adequate share of the available time?

5. How much time is being spent by students on school work, and is this amount of time adequate?

6. How can we achieve, for each individual student, a more adequate match between time needed and time available and used?

The Importance of Time

Time has substantial intuitive appeal as an important contributor to achievement. It is easy to understand the statement that the more time is spent on a task the more is accomplished. Payment on the basis of time worked is an accepted feature of the workplace. Athletes, musicians, soldiers and many other kinds of performers know that the time spent in training and practice is a crucial factor in performance. While it is not clear whether time is more important than talent in reaching outstanding levels of academic attainment, it is accepted that spending more time at an activity is important to success in that activity.

The importance of time for learning can be examined more clearly by reference to an instructional model proposed by John Carroll in the early 1960s.[1] According to Carroll, amount learned may be treated as a function of the ratio of time spent to time needed. Time needed is related to aptitude (or talent) and to the quality of instruction. Time spent is a function of time available and persistence or motivation (the willingness of the individual to take the necessary time).

This model has been used as the starting point for a large body of research on instructional time. The major branch of this research is based on an extension of the model by Benjamin Bloom, commonly referred to as mastery learning.[2] Bloom's basic thesis is that almost all learners can be brought to an accepted level of performance by giving each individual sufficient time. In particular, what is required is that each learner take as much time as needed to reach the desired level. Research in a wide variety of settings has shown that learning can, indeed, be improved by varying the time allocated to suit individual requirements. A major problem with Bloom's model is that its application requires a substantial shift in the way in which schools arrange their time schedules. This point will be addressed more fully later in this chapter.

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[1] Carroll, J.J. A Model of School Learning. **Teachers College Record**, 64, 723-733, 1963.

[2] Bloom, B.S. **Human Characteristics and School Learning**. New York: McGraw-Hill, 1976.

It is possible to identify a second branch of research on time which is more directly linked to ordinary school and classroom practices. Early work in this area, such as that of David Wiley,[3] examined quantity of schooling, in terms of obvious variables such as length of school day and year and absenteeism. Such research indicated that even such global variables were significant predictors of school achievement. More recent research has focused on time use in the classroom itself.[4] Again, a clear relationship can be shown between achievement and variables such as the amount of time spent on academic activities and time on task for an individual student.

Overall, therefore, it is reasonable to conclude that more time and better use of time can have a significant impact on achievement. Unfortunately, it is not possible to predict exactly what gain would result from changing time allocations in a specific way. We do not know, for example, whether it would be better to add to the school year or to the school day, whether a tightening of the school schedule would be more effective than adding to total time, or whether homework or study time is as productive as class time. These are important limitations, because there are substantial differences in the cost of different forms of time allocation. As far as can be determined, no analysis has ever been done on the cost-effectiveness of particular approaches to allocating time. Much would depend, in any case, on what teachers, students, and the public at large would find acceptable.

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[3] Wiley, D.E.. Another Hour, Another Day: Quantity of Schooling, a Potent Path for Policy. In W.J. Sewell et al (Eds.), **Schooling and Achievement in American Society**. New York: Academic Press, 1976, pp. 225-265.

[4] Denham, C. & Lieberman, A. (Eds.). **Time to Learn.** Washington, D. C.: U.S.Department of Education, 1980.

The specific time proposals presented in this chapter are based on the premise that additional time and better time use can be a major ingredient in our attempts to raise achievement levels. Certain judgements are made as to the most efficient ways to gain the additional time. Some trade-offs will, of course, have to be made both for reasons of cost and because there are some strong constraints on the system as a whole. For example, it would be unlikely that the public would support or pay the cost of adding yet another year to secondary schooling or to undergraduate university education. Nevertheless, within these broad constraints, many changes can be made which can be expected to contribute to improved achievement.

A couple of notes of caution are in order. First, no time-based model of learning says anything about what **should** be learned. Presumably, trivial as well as important things can be learned more effectively with more time. As our discussion of curriculum indicates, much needs to be done in reworking the curriculum in science and mathematics. Second, the priority of science and mathematics in the overall curriculum must be decided. If there are constraints on total time, the problem becomes one of what trade-offs to make among the competing demands on the time available. Finally, it is important to point out that quality of instruction is an inherent part of the time model itself. If instruction is poor, more time will be needed. At the same time, time management is, in itself, an important element of effective instruction. The link between time and quality of instruction is more complex than that between time and content. Good instruction can reduce the time needed while making more effective use of time allocated. The opposite is true for poor instruction.

Years of Schooling

The total time available for learning may be seen as the sum of three variables, total years of schooling, length of school year, and length of school day. A fourth variable, time spent by students outside of school hours (homework time), may also be added, but this variable is more conveniently considered under the heading of student workload or persistence than under total school time. The three main contributors to total time are examined in this and the following two sections.

As we are all aware, the total period of schooling in this province has recently been increased by one year with the introduction of grade 12. This has brought the length of elementary and secondary education in this province into line with most of the rest of North America. Although the impact of this increase has been far-reaching, a strong argument can be made that the increase has had no influence on learning at any level below senior high school. It has also had little impact on the content of mathematics and science programs (although there has been substantial impact on participation in some courses), since courses in these areas were not changed in any significant way with the additional year. In fact, it can be shown that the total time available for specific mathematics and science courses has diminished rather than increased under the new system. The additional time has been used up in broadening the program to include a variety of new courses not available within the previous program, a trend which we have already argued against in this report.

In principle, there is nothing sacred about twelve or any other number of years of elementary and secondary education. Nevertheless, whatever the need for additional time, it is unlikely that the public would support the addition of yet another full year of schooling at this time. In fact, Ontario, the only province with such an additional year, has recently reduced its program to the normal twelve grades, while permitting some room for extension for students to take advanced courses. In any case, a more plausible argument can be made for adding time at the post-secondary level, or for increasing participation at this level. We therefore remove this possibility from further consideration in this discussion.

Length of School Year

This brings us to the question of length of the school year. At 180 days, the student year in this province is comparable to those in the other Atlantic Provinces, but is generally shorter than those in Western Canada. For a province with chronically low achievement, it seems odd that we have persisted in keeping one of the shortest school years in the country. While we cannot guarantee that increasing the length of the school year would, in itself, create a turnaround in achievement, the evidence on time is compelling enough to justify such a step. Such a move would have the advantage of influencing achievement at all levels. A further attraction of this step is that is would convey a highly visible signal of an attack on the problem of low achievement. The public impact of such a move would have ripple effects throughout the system, thereby enhancing the effectiveness of other measures being suggested in this report. As part of a broad package of changes designed to improve achievement levels, adding a few days to the school year would seem to have distinct merits.

There are two potential obstacles to taking this step. First, our public opinion poll suggests that citizens of the province are satisfied with the school year as it is. It is not clear how difficult it would be to persuade the public that adding time to the school year would be desirable. However, we suspect that the public would not be adverse to such a move if presented specifically in the context of improving achievement.

The second and more major obstacle is the reaction of teachers. While teachers have been vociferous in supporting the argument that existing time for mathematics and science is insufficient, it is unlikely that they would accept an overall increase in workload without additional compensation or some other trade-off. Certainly, most teacher arguments on this point have been made in the context of reducing the emphasis on some other parts of the curriculum in order to find the required additional time. With other moves which might be made to improve the circumstances under which teachers work, the possibility of appropriate trade-offs does exist. The ultimate cost of the move would nevertheless be strongly dependent on the outcome of negotiations with teachers on this issue.

Recommendation 10.1

That the length of the school year be increased by ten days at all levels from primary to senior high school.

Exactly the same line of argument holds for the length of post-secondary terms and years. Universities, in particular, have had a tradition of exceptionally short teaching terms. There is, however, no fundamental reason behind the traditional twelve or thirteen week semester, or the long breaks between semesters. It is obvious that the intensive pace of university courses can be directly associated with both the length of year and the time per day or week devoted to instruction. A great deal has to be accomplished in a very short time. It is notable, for example, that other post-secondary institutions take substantially more time than universities to cover essentially the same first-year material in mathematics and science.

It is obvious that any proposal to increase the length of the university year would be fraught with problems. There is little need to elaborate on the impact on summer work for students, research patterns, examination schedules, and other long-standing traditions and habits of university faculty and students. Nevertheless, none of these points is fundamental, and none makes the basic time argument any less sound. In any case, there are precedents within universities, in that faculties which judge their time demands to be greater than normal often add a week or two to a term. Universities have substantially more flexibility than other institutions to adjust schedules and workloads to allow for additional time. The only limitation within the local university setting is that a substantially longer semester would remove the possibility of operating a third semester each year. In our estimation, the loss of the third semester would impose strains on existing resources which would offset any gains made in time within a semester. Nevertheless, even a modest gain in time would relieve some of the pressure under which students now find themselves, and would also convey a message that higher achievement is the goal.

Recommendation 10.2

That the length of the university semester be increased by one week.

As for the other post-secondary institutions, their terms are generally much longer than those at the university. It is therefore more difficult to make an argument for a general lengthening of the term. At the same time, the amount of student in-class time is also much greater than at the university. This constrains any proposal to add instructional time within the week. These institutions have other unique problems, such as the proportion of students accepted who have been out of school for a year or longer. Rather than making specific time recommendations, therefore, a broader model is to be proposed in a subsequent chapter, based on a more generic approach to first-year programming in these institutions, as discussed in an earlier chapter.

School Day

Like the school year, the length of the school day is essentially arbitrary. It is a measure of how firmly certain aspects of schooling are entrenched, that the idea of a five hour school day has persisted in the face of major changes in transportation patterns, out-of-school responsibilities of students, total demands on school time, and so on. At the same time, it is also interesting to note that the school day has not been shortened to the extent that has been true for the working day for most workers. Like many other aspects of schooling, the school day is firmly established, and is generally not seen as a variable which can be altered to meet changing demands in the system.

One of the complicating factors about the school day is the general expectation that school work continue to at least some extent outside of normal school hours. Homework, for both teachers and students, is an accepted part of school life. In the case of students, it is easy to make the argument that time in school is likely to be more productive than time at homework, particularly since there are clearly wide variations in the time students actually spend when free to choose. Adding to the school day while reducing homework would therefore seem to be a desirable thing to do. Even more desirable, from the perspective of our time model, of course, is to add to both. The only limitation is the total time available in a day, and the necessary allowances for other essential daily activities. For teachers, the picture is different, of course, because any additional time spent teaching cannot be traded off against homework. Additional teaching time, in fact, is likely to add directly to the teacher's homework. Again, the total time available in a day is the major constraint.

Studies of students' out of school activities suggest that considerable time is available outside of school hours. The Task Force survey of high school students, for example, revealed that the average student spends more time watching television than doing homework or studying. Adding time to the school day might alter this balance somewhat in a desirable direction.

Teachers, of course, would present strong arguments about student fatigue at the end of the school day. Whether the normal drop in productivity at the end of the day is genuine fatigue or simply anticipation of being free from the constraints of the classroom is unknown. However, it is difficult to imagine high school students, for example, being seriously fatigued at the end of the normal school day. Teacher fatigue is another matter. It is obvious to anyone who spends time in classrooms that teachers are subjected to moment-to-moment pressures which are much more intense than those encountered in most workplaces. More will be said on this issue in a later chapter. The main point here is that teacher workload, more then that of students, is likely to be a limiting factor in any move to lengthen the school day.

Considering these and other factors, it is difficult to make a clear case for a general lengthening of the school day. However, it is possible to move in a slightly different direction which would increase flexibility and achieve some of the potential gains from a longer day. These moves have to do with reducing time losses within the day, more systematic approaches to homework, increasing school opening hours, and the like. These factors will be considered subsequently.

Class Hours in Post-Secondary Institutions

Unlike the regular day schools, post-secondary institutions are not organized on the assumption that all hours of the day are filled by classes. This yields an additional area of flexibility in time. University students may have as few as fifteen hours per week of class time even when carrying a regular course load. At other post-secondary institutions, total class time is much greater. Nevertheless, there is no assumption, as in high schools, that students will be in class during all hours the institution is open. Post-secondary institutions are distinguished from elementary and secondary schools by being open for much longer hours. Libraries and other facilities are typically open to students on evenings and weekends, for example - something which is rarely seen in regular schools.

The other major factor which distinguishes the university from other institutions is the teaching load of staff. University professors typically spend less than half the time in the classroom than their counterparts in other post-secondary institutions or the regular school system. The conventional argument for this is that professors are obliged to spend substantial time doing research. It is not within the mandate of this study to assess the actual research load or performance of professors. However, a couple of points are relevant to the present discussion. First, it is surprising, given the amount of time that both professors and students are free from regular classes, that very little time seems to be spent in one-on-one sessions between students and their instructors. According to students' reports, they rarely approach their instructors for individual help, preferring instead to get such help from their friends. More important, it is surprising that more time is not spent on formal tutorial or other help sessions, especially in mathematics, where the risk of failure has been so high.

In our view, the failure to allocate additional class time in mathematics, when the problems are obviously so serious, amounts to something close to negligence on the part of the Mathematics Department at the university. There is nothing sacred about three or four or any other number of class hours per week. Unlike many other subjects, science and mathematics require intensive practice and problem-solving time, rather than extensive reading. Most other science subjects have long recognized this, and have required essentially double the amount of class time compared to other subjects. There is no reason why mathematics cannot operate as other science courses, by holding regular laboratory sessions, where students can gain necessary practice under structured conditions. Neither students nor instructors are occupied by class time to the extent that this could not be achieved. We therefore recommend:

Recommendation 10.3

That all first-year mathematics courses be accompanied by three-hour per week laboratory sessions in addition to the normal lecture time.

The major obstacle to implementing this recommendation in the short term may be that of space. Memorial University has suffered from a growing space shortage for several years. It is not clear if the capital funding will be available to create the additional space needed. As indicated in Chapter 7, our perspective on this is that the St. John's campus of Memorial University should not continue to expand to accommodate even more first year students, but that the community colleges should begin to absorb most of the load at this level. This, of course, does not reduce the demand for space - it merely shifts it elsewhere. At some point, government will have to address the space problem. We would merely remark at this point that any provisions for either space or staffing for the community colleges should take into account the above recommendation, and allow for substantial additional class time for mathematics courses.

Time Lost

Throughout the course of this investigation, the attention of the Task Force was drawn on numerous occasions to the many sources of lost time within the school system. At the senior high school level, for example, a regular two-credit course is supposed to correspond to 120 hours of instruction. Virtually everyone consulted agreed that the actual time available is nowhere near this amount. High school teachers themselves estimated that the average is about 89 hours, and this estimate failed to allow for such things as transition time between classes. Is it any wonder that teachers complain about not being able to cover the course material?

One of the greatest problems encountered in discussions with school personnel is that there was no clear agreement about which time losses are legitimate or about which losses can be recovered. Most teachers and school administrators consider such things as winter carnivals, graduations, photographs and sports days to be legitimate parts of the school program. Most of the demands being placed on school time by community groups, health agencies, researchers and the like are also considered to be important. Public opinion seems generally on the side of schools doing more rather than less of this sort of thing. What, then, are the possibilities for reducing lost time?

At the senior high school level, the school year is substantially reduced by a lengthy examination period. This partly is a consequence of merging the public examination schedule with regular school examinations, and of the large number of subjects examined. This affects students in all senior high school grades and, in some cases, extends as far down as grade 7 because of the perception that all students in a school should be on the same schedule. It is common to see three full weeks of the school schedule devoted to final examinations. Compounding the problem is the widespread practice of holding a similar set of mid-term examinations. Worse, some schools hold what is termed "pre-publics" or dry runs for the public examinations. While the latter practice varies from school to school, it is not uncommon for schools to occupy eight to ten teaching days for mid-term examinations and several further days of rehearsals for the public examinations.

During examination periods, all regular classes are usually cancelled. It is not uncommon for students to have several days in a row with no examinations, and other days with only one. The important question, of course, is how do students spend the time available? We do not know for sure, but there are strong indications that many see this time as time free from school work. Students can do little except review work during this period. No new subject matter can be introduced. If we consider that one of the main complaints of teachers is that there is insufficient time to cover the mathematics and science courses, then any time which can be recovered from examinations is added time for course coverage. In any case, a strong argument can be made that review conducted under the direction of the teacher is likely to be more productive than independent student work.

There is no fundamental reason why so much time needs to be taken for examinations. The issue is entirely one of scheduling. Mid-term examinations can just as easily be conducted as part of the regular class schedule as outside the schedule. Indeed, some schools have already moved in this direction. As for the public examinations, there is no reason, other than the relatively small cost of employing supervisors, not to revert to the earlier practice of holding these after the end of the regular year. If this is done, it is but a small additional step to hold final examinations in all senior high school courses during the same period.

Recommendation 10.4

That all mid-term examinations in the intermediate and senior high school grades be conducted in regular class periods, using up to two periods as necessary.

Recommendation 10.5

That all final examinations in senior high school courses be conducted outside the regular school year.

It might be added that the effect of these two recommendations would be to achieve a gain of as much as 10 to 15 days in the school year at the high school level. The cost of this move would be somewhat less than that for lengthening the school year. The main cost factors would be payment for supervisors and for marking. It is therefore attractive to suggest that this be used as an alternative to lengthening the school year. It is important to note, however, that the proposal to lengthen the school year applies to all grade levels. The losses referred to in this section are unique to high schools, and should be corrected at this level. The basic principle is that more time is needed throughout. How much time and how it is achieved are matters for negotiation and, ultimately, matters of cost.

A second area of loss at the secondary level is the time used in class changes. An estimate made during an observational study of science classes in 1987 places the average time lost in transitions at about seven minutes per class period. Teacher estimates from our survey suggest that the loss is about one minute. However, the teacher estimates do not take into account the short period of off-task discussion which commonly occurs at the beginning of a class session. There is probably little that can be done about this other than exhort teachers not to allow such discussion to get out of hand. What can be done, however, is to allow a small amount of time in the school day for transitions, and not have this counted as instructional time. Such a move is fairly easy to make, and could yield a gain of perhaps 15-20 minutes per school day.

Recommendation 10.6

That time be allowed in high school schedules for class changes, and that this time not be considered part of the instructional day.

Our impression is that much less time is lost at the primary and elementary levels than in high schools. In particular, the problems discussed above are essentially characteristic of high schools. One of the major problems at the lower levels lies in the variability of time allocations and usage. This point will be discussed in the next section.

Time Allocations to Subjects

Thus far we have looked only at ways of increasing total time or of recovering lost time. The second major aspect of time is its distribution among the various parts of the curriculum. In many ways, this is a much more difficult issue, because it requires judgements of the relative importance of subjects, or more troublesome still, of their relative difficulty for students. There is already substantial pressure on the curriculum, only some of which can be relieved by adding to total time in the ways already recommended. Many external agencies are lobbying for further additions to the school program. There is clearly a general expectation among the public that the schools should do more of everything. Nevertheless, there is also some sense in the public's mind that some things are more important than others. The broad issue of priorities has already been addressed. Here we extend that discussion to the specific level of time allocations.

In Chapter 3, it was argued that science and mathematics must be among the highest priority subjects in the curriculum. If, as the evidence indicates, these are also subjects which present substantial difficulties for students, then a clear case exists for allocating as much time as necessary to these subjects to ensure that students succeed. If this has to be done at the expense of other subjects, this is the way it must be. The only limitation to this would be if the time demands conflict with those of equally high priority areas such as language development, or if it is clear that further time allocations would yield diminishing returns.

It is estimated that the proposals already made for adding to the school year and reducing lost time would result in a gain of about 30 days, or 15 percent per school year at the high school level. If the estimates of the real reduction in instructional time are correct, these proposals would still not be sufficient to bring the number of instructional hours in high schools up to what is required. In any case, given the problems of achievement in mathematics, and of scope in science courses, it would make sense to err on the side of having too much than too little time.

Specifically, it may be argued that the proposed gains in total time would perhaps be sufficient to allow for the additional depth of treatment required in science and mathematics. Beyond this, however, there are pressing demands for laboratory work and problem-solving. Science and mathematics are fundamentally different from most other subjects, in that it is not possible simply to read from texts and other sources to gain the required knowledge. Practice in solving problems and hands-on experience in a laboratory setting are essential to developing adequate understanding in these areas. These are inherently time-consuming activities which cannot be properly done outside of school time. Most high school students cannot rely on their parents to help with these subjects, nor are the required resources available at home. A strong argument can therefore be made that more class time, and perhaps less homework time, is needed in science and mathematics than in other subjects.

If we are prepared to accept the idea that the high school curriculum should have greater depth in basic academic areas, and that further broadening should be avoided, then there is already some scope in the last three years of school for adding some time for science and mathematics. The school timetable does allow for the equivalent of fourteen credits per year, although only twelve are required. Rather than using the additional time for elective subjects, as is now done, it is clear that a much greater need exists in some of the basic academic areas, particularly those of direct interest here.

Specifically, what is proposed is that time for laboratory and problem-solving activities be allocated over and above the normal class schedule. The addition of only one class period per week (or cycle) to a subject would yield an additional 15 percent to the time available for that subject. Interestingly, this is as much as has been added by all of the earlier proposals. This therefore seems to be an obvious way to gain time.

Recommendation 10.7

That one additional class period per six day cycle be added to the school schedule in science and mathematics courses, to be used specifically for laboratory and problem-solving sessions.

It is recognized that this recommendation presents a major problem from a timetabling point of view. School schedules are almost always organized in time periods of three or six class periods per cycle. Administrators have argued that adding time in units other than these would create serious scheduling problems. Consideration was, in fact, given to a proposal to add three rather than one period for this reason. However, calculations soon revealed that this would create even more serious constraints for students who decide to concentrate on the sciences. In any case, what amounts to a 50 percent increase in time could hardly be justified.

In the final analysis, it must be argued that the school timetable should be subordinated to the demands of the curriculum, not the other way around. There is nothing inherently superior about the current seven period day or 42 period cycle. Its only advantage is neatness. Many institutions run much more complicated schedules than do schools. Most post-secondary institutions, for example, simply extend their hours of opening to accommodate overlapping schedules and other conflicting time demands. There is no fundamental reason why schools cannot do the same. It is left to the ingenuity of administrators to translate what is judged to be an essential requirement into a workable schedule.

The problem of time allocations in elementary schools seems to be one of variability. Our own surveys showed large variations in time allocations to both mathematics and science (**Background Report #10**). It is also clear that the time actually used is somewhat less than that allocated, although the difference does not seem to be as large as that in high schools. It is not at all clear that these differential allocations are in any way related to the needs of students. Certainly any loss of time for these subjects can only be seen as detrimental. What is required at this level is a clearly defined basic time allocation, with variations for individual students, as discussed in the next section. To this end, it is recommended:

Recommendation 10.8

That the minimum time allocation for mathematics be one class period per day in primary, elementary, and intermediate schools.

Recommendation 10.9

That the minimum time allocation for science be one class period every two days at the primary and elementary levels and one class period per day at the intermediate level.

Differential Time Allocations for Different Needs

The basic time model used as the starting point for this discussion is based on the assumption that students of different aptitudes will require different amounts of time to learn. This concept provides a basic premise for such approaches as mastery learning and various other schemes for continuous progress through the school system. The model suggests an ideal, under which each student would be given just the amount of time needed to achieve a particular learning goal, and in which all students could ultimately achieve at approximately the same level.

This model, of course, is in fundamental contradiction to the way in which schools are typically organized. Under our usual graded school organization, all students are given essentially the same amount of time to progress through a specific amount of curriculum content. The only departures from the fixed time model are for remediation or its more extreme version, repetition of a grade. The latter has largely gone out of fashion, for reasons having to do with the social development of children and the perceived need to have students progress along with their peer group. Remediation is also generally regarded as something done under fairly extreme conditions, and is not treated as part of a normal need for differential time allocations.

It is clear that the fixed time model, with all students progressing at the same pace, results in ever widening disparities in student attainment as a particular group progresses through the system. It is common for students in the same grade 7 or 8 class to differ by several grade levels in their reading ability, for example. The most common answer to such disparities has, of course, been homogeneous grouping or streaming, in which students of nearly the same ability are placed in the same class. However, streaming has been shown to have largely negative effects on lower achieving students.[5] This effect can be predicted from the time model, since streaming does not allow for additional time allocations. Instead of providing opportunity to learn, ability grouping often simply removes the need to learn. Fortunately, ability grouping has largely disappeared from elementary schools, though not yet from secondary schools.

Different time allocations for students of different aptitude is clearly a desirable alternative to streaming. The essential problem is how this can be accomplished. Various kinds of differential time models have been tried over the years. Non-graded schools, continuous progress, individualized instruction, and similar terms have been used to describe such systems. All of these, of course, require fairly drastic changes in our thinking about how schools are organized. Unfortunately, the notion of gradedness is strongly entrenched in the minds of both educators and the public. There are also strong arguments for having students progress with their peer group. In any case, it is difficult to predict the consequences of having some students take several years longer than others to progress through elementary and secondary schools. Studies of dropouts have shown, for example, that falling behind their peers is one reason why students leave school early.

What is required is obviously some solution which avoids the problems of both streaming and an extreme form of continuous progress. First, however, it is necessary to reiterate the general principle stated in Chapter 3, that the goal is to attain a common high standard of learning for all students in basic academic areas, and to link this concept to that of time. The basic intention here is to reduce the gap in achievement between students at the same level of schooling, and to prevent this gap from becoming so wide by the time students reach high school that it is essentially impossible to close.

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[5] Oakes, J.. **Keeping Track: How Schools Structure Inequality.** New Haven, Conn.: Yale University Press, 1985.

Recommendation 10.10

That the principle of differential time allocations replace that of differential programs as the primary means of accommodating individual differences in aptitude for learning.

Accepting the constraint imposed by total years of schooling, we are left with only two possibilities. The first is different lengths of school day or year for different students. The second is to establish priorities in what is to be learned, and to reduce the time allocated to lower priority areas in the interest of higher priority learning. As it happens, neither of these is especially radical in principle. Teachers have always made arrangements for extra time after regular school hours for students having difficultly. Parents frequently hire tutors to provide additional instructional time for their children. Ideally, students needing the most time to learn would be expected to spend more time at homework. At the high school level, summer schools have become fairly common as a means of allowing some students to catch up. As for priorities, regular remediation in schools is based on the premise that some subjects can be sacrificed to ensure higher levels of learning in others. In any case, our basic framework is one which requires that such choices be made when there is insufficient time to do everything which might be thought desirable.

The basic problem with the current system is that such measures are generally considered to be extraordinary rather than as normal means of improving achievement. As long as we accept a model based on the inevitability of large differences in achievement, these procedures are applied only in extreme cases in a remedial fashion. What is required is a basic shift in thinking, to an acceptance of time needed as a continuous variable which must be manipulated in such a way as to minimize achievement differences all the way through the school system. As for the specifics of school organization, the following recommendations are made as suggestions. It is recognized that there may be many other ways of achieving the same end.

Recommendation 10.11

That school opening hours and teacher assignments be made more flexible, to allow teachers to spend more time with students who need it.

Recommendation 10.12

That school schedules and student programs be designed to allow for differential time allocations in basic subject areas. This should be accomplished by having students who need more time take fewer optional courses, particularly at the intermediate and senior high school levels.

Recommendation 10.13

That summer sessions be made a regular feature of the school year, and that students failing to achieve at specified levels be required to complete such sessions before advancing to the next grade.

Student Workload and Habits

Various sources of information and opinion on how students spend their time were available to the Task Force. The subjective data give a contradictory picture. Teachers at all levels were almost unanimous in the view that students do not spend anywhere near enough time at school work outside of regular class hours. On the other hand, university students interviewed complained of the almost overwhelming workload and the substantial time pressures under which work must be done. The same students, however, admitted that they did not work very hard in high school.

Somewhat more objective data are available from the surveys. On average, high school students reported spending 5.4 hours per week at all homework, approximately two hours of which is on mathematics. Most post-secondary students indicated that they spend 2 - 5 hours per course each week at study and assignments in science and mathematics courses. Although this does not seem very high, most students reported that they found it difficult to keep up with assignments and study. Relatively few students at any level spend much time at paid work. As for leisure time, high school students reported an average of just over six hours per week watching television, and four hours per week at sports activities. It is interesting to note that some 40 percent of first year university students reported taking less than a full load of five courses. Around 30 percent had dropped courses in science or mathematics.

It is clear from both the survey and opinion data that high schools students spend relatively little time at homework and study. Obviously, high success rates at this level can be achieved with only a small amount of work. As has been argued throughout this report, however, high success rates and high achievement levels are not the same thing. The fact that students can succeed with such little effort reinforces the basic thesis that achievement expectations are low.

Conventional estimates for university courses suggest that about two hours of out-of-class work is required for every hour of class time. This yields a 45 hour week for a student carrying a regular five course load. It is clear that this is not being achieved by many first-year students at Memorial University. It might be argued, of course, that the expectation is excessive, given that most workers in our society enjoy a 40 hour week or less. One might counter this argument by pointing to the shortness of the university term and to the fact that individuals in the professional occupations to which many university students aspire are often expected to work much more than the normal 40 hours.

Students at other post-secondary institutions spend about the same amount of time at homework and study as university students. However, this means that their total workload is substantially greater because they have much more class time. Considering the fact that teaching terms are much longer at these institutions, it is clear that there is little to criticize about time allocation and use for such students.

It is important to point out that our own analysis has revealed a positive relationship between student reports of time spent and student achievement. This result is in accord with other studies of time and achievement. The problem is how to suggest an effective means of having students spend more time. Certain things are not within the control of the school system. While it is easy exhort students to spend more time at their studies, it is a different matter to formulate specific recommendations on student work habits. The target is too diffuse for any such recommendations to have much effect. We therefore confine ourselves to a general observation on the matter, in the hope that students will accept the basic proposition that time is important, and that parents, teachers, and others will attempt to reinforce this point.

Spending more time at school work is an effective means of improving achievement. Every opportunity should be used to reinforce this way of thinking, and to ensure that students are encouraged to spent as much time as possible at homework and study.

Aside from the question of attempting to bring about a general increase in time, the model used here indicates that time needed is likely to vary substantially from student to student. Efforts are thus required to establish the idea of differential time needs not only in school but in homework and study as well. Here a specific recommendation can be made, since actual homework assignments are a matter for school decision. This recommendation is designed not only to reinforce the principle of differential time needs, but also to convey this concept to parents.

Recommendation 10.14

That homework assignments be specifically tailored to student time needs, that the cooperation of parents be solicited to ensure that the reasons for such assignments are clear, and that materials be prepared to assist parents in helping students with homework.

Summary

What has been proposed in this chapter is nothing less than a fundamental shift in thinking from differential achievement as an inevitable consequence of differences in student aptitudes, to higher and less differentiated achievement levels based on time allocations matched to student needs. Once we accept this basic shift, the problem becomes simply one of how to achieve some gains in total time and, more importantly, how to bring about differential time allocations for different students. It has been argued that substantial total time gains can be achieved by a series of fairly modest changes in the school year, in daily schedules, and in subject priorities. As for differential time allocations for students, we have not gone as far as some others in arguing for some variation of continuous progress, because the long term consequences of this for organization of the system and for student progress through the system have not been fully worked out. Instead, it has been argued that some further modifications in schedules and student programs could yield the time necessary to improve achievement generally and to reduce the gap between the highest and lowest achievers.

Time is not everything, of course. Additional time allocations are not a way to compensate for inadequate curriculum, poor teaching, or other flaws in the system. A major advantage of working within a time framework, however, is that time is an easily understood and easily manipulated variable. In our estimation, not enough use has been made of time as a variable in learning. The proposals made in this chapter have been designed to allow for a more strategic approach to time allocation and use.

CHAPTER 11

TESTING AND EVALUATION

Grades are the currency of the school. Whatever their value as measures of the important outcomes of schooling, numerical grades, usually based on test scores, constitute the main source of evidence on student performance while in school, on preparedness for the next stages of education, or on eligibility for a variety of society's rewards, from scholarships to initial job entry. As we have seen in earlier chapters, test scores are also a main source of evidence on the effectiveness of the system as a whole. Major judgements affecting the fate of both students and programs rest on the use of scores. From the sources of information available to this Task Force, it is evident that the public places substantial confidence in testing as a means of judging whether the system is performing well or poorly.

Some might argue, of course, that the system is too reliant on testing, and that many important outcomes of schooling cannot be measured by any existing type of instrument. Part of this argument is accommodated in systems of evaluation which allow marks to be given for performance in situations other than tests. In our system of shared evaluation, for example, teachers may use a variety of evaluation criteria including assignments, projects, participation, and the like in arriving at a grade. What is important to note, however, is that teacher judgements in such areas still have to be translated into numerical grades before they can be used in the system. In a broader sense, the system is essentially incapable of accommodating non-numerical judgements. Whether or not tests form the basis for grades, the latter remain the only long term reminder of how students do in school and how schools themselves perform.

In this chapter, a number of aspects of the evaluation system are considered. The basic position taken is that rather than decrying the overuse or inappropriateness of tests, we should attempt to ensure that testing is used strategically, and that the testing system is as comprehensive as possible with respect to agreed-upon outcomes. At the same time, it is argued that substantial reforms are required in our testing programs to bring these up to accepted technical standards and to achieve the kind of comprehensive coverage of the curriculum which is desired. First, certain further concepts are developed which underlie the development and use of tests and the interpretation of test scores. The major testing programs in place in this province, particularly the public examinations and the Standards Testing Program (CTBS), are then examined. Finally, some observations are made about the use of tests and other evaluation tools in schools and post-secondary institutions.

Validity and Reliability

A test is said to be valid to the extent that it measures what it purports to measure. It is said to be reliable to the extent that it does so in a consistent fashion. These two simple concepts underlie what many might see as one of the most highly technical aspects of education, that of testing. Few of the technical issues will concern us here. What is important, however, is to understand that the whole purpose of test development is to create measures which are as valid and reliable as possible with respect to important outcomes of schooling.

Of the two concepts, validity is the most important and most difficult to achieve. Some indication of the major difficulty may be given with reference to the issue of the objectives of mathematics and science teaching discussed in Chapter 3. If such goals as science for citizenship or mathematics for problem solving are to be put forward as important outcomes, then the public has a right to expect that those tests which are used as final measures of how well a student has done in school should give some indication of whether the student is knowledgeable about current issues of science and society or of the use of mathematics in problem situations. A glance at most of our public examinations would soon reveal, however, that such objectives are by no means prominent in the content of these tests. What is prominent is specific subject matter knowledge. It takes a substantial leap of inference to interpret the results of such tests as saying anything about these broader objectives. In a fundamental sense, therefore, it may be argued that the public examinations, and perhaps many other commonly used measures, are invalid.

It is much easier to construct reliable tests than valid ones. A test may, in fact, be reliable without being valid, in the sense that it may measure the wrong thing consistently. (A test cannot be valid without being reliable, however.) The most important aspect of reliability in large scale ongoing testing programs such as the public examinations is to ensure that the examinations are stable from year to year, or that any changes are deliberate and can be detected. Nevertheless, no provision has ever been made for determining the stability of public examinations, much less of tests used in schools. This makes it essentially impossible to determine whether students are performing as well now as in earlier years. Tests given by the post-secondary institutions are fundamentally no better in this respect, although the insistence on criterion-referencing makes it easier to detect shifts in test difficulty.

Further Observations on Secondary and Post-Secondary Achievement Results

In an earlier chapter, several important points were made about the interpretation and use of test scores. In particular, it was argued that scores may be interpreted in either a normative or a criterion-related sense. A normative interpretation is one which compares students with each other or with a set of norms (the CTBS is such a measure). A criterion-related interpretation is one which says something about the actual achievement of a student on some body of knowledge, without reference to the performance of other students. These concepts, along with the concepts of reliability and validity, are now used to help explain some of the results reported in Chapter 4.

On the surface, the high success rates in mathematics and science on the public examinations seem reassuring. Taken at face value, these results suggest that students are doing very well indeed, and that there has been no recent deterioration in performance. However, a closer analysis of some of the underlying features of the system reveals some serious flaws, which cast doubt on the usefulness of these results as indicators of the level of performance of the system.

As mentioned above, it must be recognized that the reliability of the public examinations is open to question. No procedures are in place to ensure that the examinations are of comparable difficulty from year to year. School evaluation procedures are even more variable, as there are few guidelines to schools as to the standards to be attained or the specific kinds of measures to be used.

In light of this, one might ask how it is that the results are so remarkably stable over time. The answer is clearly that the system functions on a normative level from year to year. A variety of implicit and explicit mechanisms are in place to ensure that the results remain stable. In the case of school marks, one can expect stability simply from the fact that results over a large number of schools are being averaged. Even a set of random numbers would be stable under such conditions. In fact, both school and public marks vary widely from school to school, in such a way as to suggest that the success of an individual student depends strongly on the school attended.

More to the point, the only clear guideline given to schools is that they should scale marks in such a way that the average student in the province receives a score of 65. While teachers have to make some judgement as to whether their students are above or below average relative to the province as a whole, they do not have to associate this judgement with any particular level of student performance. The effect is to force a normative judgement, based on relative standing of students, rather than a judgement based on a specific level of attainment in the course. On average, it appears that schools believe their own students to be somewhat better than average (the mean school mark is generally higher than the 65 guideline).

Essentially the same thing happens in the public examination itself. Since there is no control of test difficulty, it is simply assumed that performance is stable from year to year. Tests are constructed and marked with normative expectations in mind, to the extent that the expectation becomes a self-fulfilling prophecy. If scores in any year are significantly lower than those in previous years, scaling is used to bring the aberrant scores into line. Significantly, this does not happen if the scores are higher. In fact, such scaling is rarely necessary. Marks coming from the schools are generally high enough to offset the fairly low marks students achieve on public examinations alone. Members of the marking board understand the expectations and, although they may sometimes grumble about low standards, they do not see themselves in a position to do anything about the system. In fact, the teachers who make up the marking boards have a strong vested interest in ensuring that the final results look good. Students are given the benefit of the doubt at so many stages along the way that it becomes difficult not to pass. This vested interest extends all the way through the system, to the point where officials would likely have much to answer for if they were to present the Minister with set of public examination results which showed substantially lower pass rates than in previous years. Interviews with teachers involved in marking the public examinations suggest that an implicit scaling system is in place as the papers are marked, which ensures that marks are in reasonable conformity with expectations. These interviews also give reason to believe that there has been a decline in performance on the examinations in recent years, which has been masked by the implicit and explicit scaling procedures which are in place.

All of this suggests that the public examinations are essentially meaningless as a source of evidence on actual achievement levels or on performance trends over time. Within a given year, the results are quite adequate as a basis for comparing individual students, schools, or groups such as those in small or large schools. In these cases, only relative judgements are being made. In other words, it can reasonably be assumed that a student with higher marks has achieved more than one with lower marks, or that group differences on the same test tell us something about the groups. What is not possible is to make any estimate of specific capabilities from the marks, or to tell if achievement is the same or different from year to year.

This issue has important implications. Public confidence in education is obviously not enhanced by knowing that it is impossible to say from the public examination results that today's students perform better or worse than those of past years. As for post-secondary admissions policies, it is assumed that a particular high school average means the same thing from year to year and, more important, that it conveys a particular set of achievement expectations. Unfortunately, no assurance can be given that this assumption is valid.

It is clear from an analysis of the examination system that one of the main reasons for the apparent sudden drop in performance once students enter post-secondary institutions lies in different interpretations of high school and post-secondary marks, and on the actions taken on those marks. Public examinations, and their accompanying school examinations, have been treated essentially as normative measures. In contrast, the post-secondary institutions function in a fully criterion-referenced manner. The assumption is made that the test is valid with respect to the course content, and that a score means that a student has mastered a particular proportion of the content of the course. Furthermore, instructors and departments do not have the same vested interest in presenting high marks, or in passing particular proportions of students as is true for high school teachers. In fact, an argument can be made that the opposite is the case, with the prevailing interest in some parts of the system being in keeping success rates low, as a means of maintaining high standards or screening students for access to more advanced study. There have been too many reports of instructors predicting on the first day of classes that half their students would fail to dismiss these as isolated cases. In fact, by their own reports, many post-secondary instructors have revealed a propensity for seeing themselves as the final guardians of standards in an educational world gone soft.

This characterization of the contrast between the two levels of the system may be slightly extreme. No attempt will be made here to judge which system yields the most undesirable effects. There is much to criticize in both systems, as representing the worst in misuse of testing. What is important is that we understand the difference between the two viewpoints, and that a means be found to bridge the gap between the two.

What is interesting about the two systems is that at the most fundamental level there is no real difference. The public examinations, by virtue of their goal of certifying students for high school graduation, are in the most basic sense criterion-referenced measures. That is, anyone looking at a mark of, say, 65 in mathematics, would be entitled to believe that the student is somehow 65 percent proficient in the body of knowledge or skills represented in the course. Exactly the same point can be made about post-secondary examinations. The problem lies not in the fundamentals, but in the way in which the tests are constructed and the scores arrived at and interpreted.

Improving the Public Examinations System

From the above discussion, along with the analysis presented in **Background Report # 6,** the major problems with the current public examinations system may be summarized as follows:

1. The examinations do not properly reflect the main objectives of the courses they are supposed to represent.

2. There is no way to determine whether the examinations are stable from year to year, and hence no way to track possible changes in achievement levels.

3. Though criterion-referenced in principle, the examinations are treated as if norm-referenced. Marks are assigned so as to ensure a very high and stable pass rate.

4. The school component of the final mark is too high for the levels of achievement being attained. In particular, schools appear to inflate marks near the passing point, and assign mean scores which are higher than the recommended provincial norm.

5. There is no means of determining whether school grading practices are consistent across schools or with the public examinations.

6. The test development techniques used do not meet basic technical criteria for establishing validity or reliability.

7. In general, there is a small deficit in depth of treatment in the content of our public examinations compared to those used in other provinces.

The public examinations are a firmly entrenched part of the educational system of the province, a part which seems to enjoy both public and professional support. The essential problem is that the system has not kept abreast of developments in the field of testing over the past couple of decades, and has not fully capitalized on advances in data management and analysis capabilities. It is clear that the Department of Education has been somewhat reluctant to move ahead with reforms, for fear that a smoothly running part of the system would be disrupted. While it may be reassuring to feel that other provinces are now moving to reinstate public examinations, and have emulated our concept of shared evaluation, we also cannot overlook the fact that the systems which have recently been put into place in several other provinces are much more sophisticated, both conceptually and technically.

Within the past couple of years, the Department of Education has undertaken a project designed to yield long term improvements in the public examinations system. A feasibility study and pilot project have been completed, and an implementation proposal has been presented to government. The essence of the proposal is that the development of the examinations be placed on a more sound conceptual and technical footing, through the use of item banks, tables of specifications, field trials, item analysis, and related techniques, as commonly used in large scale testing programs. It has also been proposed that the system be made more efficient through machine scoring and the automation of routine functions such as data entry. It has been estimated that the savings achieved by automating scoring and record keeping could offset the added costs of test development, so that the revised system could operate at somewhere near current costs.

The Task Force can do no better than to endorse these initiatives, and reiterate specific recommendations made in reports to the Department on this project, which would see the major elements of the proposed reforms made a matter of policy. Accordingly it is recommended:

Recommendation 11.1

That the public examinations be explicitly designed as criterion-referenced tests, to be developed from tables of specifications which incorporate all main objectives of the courses being examined.

Recommendation 11.2

That test item banks be developed for all public examinations courses with enrolments of more than 1000 students.

Recommendation 11.3

That appropriate technical procedures be used to ensure the validity and reliability of the public examinations.

Recommendation 11.4

That procedures be developed for the automation of all routine functions of the public examinations, including scoring, data entry, and reception of marks from schools.

Recommendation 11.5

That the Department of Education employ the necessary professional staff to implement the test development system, the costs of such staff to be met mainly from savings in test scoring and data handling.

Shared Evaluation

Reforms to the public examinations, however, are only one part of the picture. Half of a student's final grade is contributed by the school. The system can therefore be only as successful as the evaluation practices used by the schools. Although the Task Force did not undertake a thorough assessment of these practices, several points are clear from an examination of mark distributions and from interviews, surveys and submissions.

First, there is little doubt that most of the marks assigned by schools come from term tests and other instruments which are designed to look much like the public examinations. Many teachers have argued that they have no choice in this matter, as long as public examinations exist. Second, school marks are given for short-term work, for which teachers expect students to do better than they do in public examinations. As we have already observed, school marks tend to be much higher than public marks, and higher than provincial guidelines for these marks. While there is an adjustment factor which modifies school marks if they depart too much from expectations, this factor does not correct for any overall difference between school and public marks, only for differences which depart from the normal expectation. Finally, no mechanism exists to determine whether school assessment practices are consistent, or to clearly identify what it is that schools are responsible for evaluating.

It might be asked, of course, why we need school marks at all, if a public examinations system is in place. There are several common answers to this question. First, it is well known that more reliable results are obtained when several measures are taken of any attribute. Taking the average of two test scores, for example, is always better than using a single test score, for fairly obvious reasons. Second, shared evaluation was introduced in the early 1970s at a time of increased professionalism of teachers, and in a spirit of giving teachers more responsibility for judging their own students. This general principle remains valid. Finally, it may be argued that some important educational outcomes cannot be adequately assessed by the usual paper and pencil test administered at the end of a long school year.

While all of these are valid reasons, these reasons have tended to become somewhat distorted in practice. Although using more than one measure does yield more reliable results, this does not ensure that the results are more valid. The practice of using school assessments modeled on the public examinations ensures that any invalidity in the latter is repeated in the former. The recent investigations of the public examinations have clearly shown that their greatest problem is validity, in the sense that they fail to address important course objectives. Ideally, school assessments should help correct this imbalance, by assessing objectives missed by the public examinations. In practice, there is little evidence that this occurs.

Rather than abandoning school assessments, as some would advocate, changes are needed which would make the school marks serve a more useful purpose. Specifically, the basic function of the school assessments should be spelled out more clearly on a course by course basis. For example, if it is judged that the public examinations cannot adequately measure such things as manipulative skills in science, school assessments should explicitly cover this objective. To the extent that school marks are to be used for improving reliability, this should also be clearly indicated. Criteria need to be developed to help ensure that schools are more consistent in their evaluation practices. The latter is a matter of program evaluation, and will be addressed in a later section. The other points are embodied in the following recommendations.

Recommendation 11.6

That the curriculum guides for all courses subject to public examinations include a section which identifies the areas of evaluation for which schools are exclusively responsible, and the proportion of school marks to be assigned to these areas.

Recommendation 11.7

That school evaluations include a component explicitly designed to overlap the public examinations, for purposes of improving the reliability of final grades.

Recommendation 11.8

That Tables of Specifications for public examinations be circulated to all schools, as a guide to expectations in the course and to school assessments.

School Evaluation Practices

The discussion up to this point has referred only to student assessment practices at the high school graduation stage. In fact, evaluation is a highly pervasive part of schooling at all levels. Considering unit tests, assignments, term examinations, standardized tests, and so on, it is estimated that the average high school student is exposed to as many as 100 different formal evaluation occasions over a school year. The influence of evaluation extends beyond this, however. Much classroom time is occupied with preparing for tests, conducting tests, and reviewing the results. Often a sort of game is played, in which students try to determine what is to be on the test, and teachers give more or less subtle clues, without actually giving away the precise content of the test. Added to all of this is the use of marks as the primary means of reporting to parents on the progress of their children.

Despite all of this emphasis, it is clear that students are assessed largely in terms of whether or not they are performing in accordance with expectations based on their past performance. A student's actual marks seem to be less important than whether or not these marks are higher or lower than expected. Greater concern is expressed when a student's marks drop off than when they are consistently low. This, of course, is an extension of the overall normative approach taken to assessment, and of the general expectation that students will vary widely in their achievement levels. If there is a core argument in this report it is that this view of achievement needs to be reversed, and that means must be found to narrow the gap in achievement in basic academic areas, specifically by increasing the achievement of those at the lowest end of the current spectrum.

If public examinations fail to meet accepted standards of technical quality, there are even greater problems with the teacher made tests used in schools. Teachers are not well trained in evaluation techniques. There exist no means of quality control of teacher tests. In fact, such tests are rarely seen by anyone except individual teachers and their students. Teachers do not have access to the resources necessary to make their tests even minimally acceptable. For example, many tests are given in handwritten form, which present a challenge for students to decipher, let alone answer properly. Marking standards are largely a matter of individual teacher judgement. Teachers' schedules do not allow much time to engage in test construction. Ironically, part of the reason for this is the large amount of time which must be taken up in marking tests.

This is not to say that school evaluation practices yield only random numbers, or that there is no value in what is being done. At a minimum, marks are reasonably reliable, by virtue of the many measures used. Teacher-made tests also have some face validity, at least with respect to textbook content. However, their validity with respect to broad objectives is open to serious challenge. It can be argued that the essential problem is that teachers do not look at tests from the point of view of their measurement properties, but rather as a means of getting at least some quantitative indicators to confirm their own judgements of student performance, of giving short term rewards to students, or of presenting to parents and administrators evidence of progress. Teachers have also argued that students expect to be tested often. On top of this, there seems to be an expectation in the system that students should be given marks for performance in a variety of situations such as class attendance, homework, or participation in discussion, as well as for attitudes and behaviour. Many of these have little to do with actual levels of achievement.

The main proposal for improving the state of evaluation in the schools is that we should reduce the frequency of testing, while improving the quality of the measures being used. There is little point in having a large number of separate measures, for the sake of reliability, or for the sake of rewarding students for short-term performance, if the measures are invalid or if large amounts of instructional time are lost in evaluation. The immediate recommendations in this area address the question of the frequency and type of measures used. The next section will deal with the question of quality control.

Recommendation 11.9

That not more than three tests per year in any course be used to accumulate marks for credit towards final grades.

Recommendation 11.10

That participation, behaviour, attitudes, and similar affective attributes not be assessed for credit towards final grades, but that these be recorded independently for purposes of reporting to parents.

Quality Control and Program Evaluation

Looking at the education system at the broadest level, it is striking how little effort is devoted to determining whether we are getting the best returns for the vast amount of public funds being invested. Although, as we have seen, substantial time and effort are put into student evaluation, school-based measures of student achievement are not particularly useful as measures of the performance of the system. The broader measures which are available, including the CTBS tests and the public examinations, have not been used as systematically as they might have been for system-wide evaluation. In any case, the normative nature of these measures limits their value for this purpose.

One example of where test results could be put to better use is for quality control at the district or school level. As was indicated in Chapter 4 and **Background Report # 1,** differences in performance across school districts are much greater than those between schools of different sizes or those in rural or urban areas. Differences between individual schools are even greater than those for districts. There seems to be little point in concentrating on school size as a contributor to achievement, as we have done in the past, while overlooking much more obvious sources of differences. Rather then seeing comparisons between districts or schools as embarrassing or as placing individuals or groups in a bad light, such comparisons should be used as a basis for focusing on specific problem areas in the system. This would yield much greater potential for improvement than more global approaches based on school size or similar variables.

Quality control means much more than student testing, however. We need to know whether our curriculum programs are being implemented properly, the costs and benefits of allocating resources to particular aspects of the system, and whether particular innovations are having the desired effects. Much of this is extremely difficult to do. Nevertheless, the investment in education is so large, and the pressures for additional resources so great, that a more comprehensive system of accountability must be developed, if we are to avoid wasting resources, or distributing resources in the areas of greatest pressure rather than of greatest payoff for the system as a whole.

It is not within the scope or mandate of this inquiry to map out a comprehensive system of program evaluation. It might be noted that the Department of Education is already making some plans in this area What might be useful would be to derive from the general principles underlying this report a few general statements which can serve as a blueprint for a more comprehensive approach to quality control in the system.

Recommendation 11.11

That all major new initiatives to be taken in education be preceded by independently conducted feasibility studies, with emphasis on the costs of the proposed initiative and the benefits relative to educational achievement, opportunity, or other important educational goals.

Recommendation 11.12

That the Department of Education prepare a blueprint for the evaluation of specific program initiatives, including new or revised courses, and that all such evaluations be conducted by a branch of the Department or an external agency independent of the agency responsible for implementing the initiative.

Recommendation 11.13

That the Department of Education, in collaboration with school districts, prepare a school program evaluation plan, and that the performance of individual schools be assessed on a regular basis using this plan.

Recommendation 11.14

That the CTBS testing program be phased out over the next five years and replaced by a set of curriculum-specific criterion-referenced tests developed locally but anchored nationally through the inclusion of items from external sources which would permit comparative analysis.

Recommendation 11.15

That scores on the above tests, along with public examinations scores, participation rates, post-secondary attendance, and similar outcome variables be used as part of the quality control system for judging the performance of individual schools and school districts, as well as of the system as a whole.

Post-Secondary Evaluation Practices

The assessment instruments used in post-secondary mathematics and science courses present fewer problems than those at earlier levels because the objectives of such courses tend to be more straightforward, and because the post-secondary system operates on a more direct criterion-referenced basis, free from some of the public pressures and expectations which impinge on the public schools. Nevertheless, from a technical perspective, many of the same problems can be found.

Although the Task Force has satisfied itself that there have been no major systematic shifts in mathematics examinations sufficient to account for the observed decline in achievement, no direct efforts are made by the institutions to ensure that such shifts do not occur. No item data or other statistics, except for mean scores and pass rates, are kept. Means and pass rates in some courses fluctuate substantially from year to year with no clear explanation. In particular, there is no way to determine if this is due to differences in test difficulty, or to other more legitimate shifts in student background, course selection patterns, or other factors. Overall, it would be difficult to defend the objectivity, stability, and fairness of student evaluation practices, should these be subjected to a serious challenge. This is not to question the integrity or professional judgements of those responsible, any more than that of teachers and school officials. It is simply to say that techniques exist for improving evaluation practices, and that these should be used more systematically. Unfortunately, statistical procedures for improving testing can be used only in courses with sufficient numbers of students to yield stable statistics. These, however, are the courses with which we are mainly concerned.

Recommendation 11.16

That testing and evaluation practices in large enrolment courses in post-secondary institutions be revised along lines similar to those proposed for the public examinations.

In an earlier chapter, a proposal was made for consolidating first year post-secondary courses, and for broadening the availability of these courses in the community colleges. This has major implications for evaluation, since the senior institutions would want some assurance that such programs meet their requirements, and that standards are comparable to what would be expected in the latter institutions themselves. We would certainly not wish to create a problem at the community college level comparable to that which has existed between the high school and the post-secondary sector. At the same time, it is difficult to argue that the senior institutions should have full control over course content, hiring of instructors, and other major aspects of community college functioning. This would tend to create a highly cumbersome system of jurisdiction. A much simpler solution would be to devise a common set of course specifications and evaluation instruments, and to use these as the basis for control of standards.

Recommendation 11.17

That all institutions in the province offering first year post-secondary courses adopt a common standard of achievement in courses having common content, that evaluation instruments be constructed and graded in accordance with commonly agreed upon procedures, and that evaluation results be used as quality control indicators.

Diagnostic Testing for Remediation

In September, 1988, Memorial University, the Cabot Institute, and the Marine Institute introduced a diagnostic inventory in mathematics for all entering first year students. The purpose of this inventory was to identify specific areas of weakness in basic mathematics, with a view to initiating appropriate remediation. Since the 1988 administration was carried out on a trial basis, at short notice, no specific mechanisms were put in place for dealing with students exhibiting particular weaknesses. In the short term, the test was useful primarily as an indicator of overall student achievement, as reported in Chapter 4. The question here is whether such a test should continue to be used, under what conditions it should be administered, and whether the results of this test should guide any remedial efforts which are put in place.

Although the test was designed specifically for diagnostic purposes, its form and content more closely resembles that which can be found in a typical norm-referenced test. The test is not keyed to curriculum content, nor is there any indication of its predictive validity. In fact, the score on this test has about the same value as a predictor of university achievement in mathematics as a student's high school mark. Results on the test, both for Newfoundland students and those in the Ontario community college where the test was developed, show that the distribution is about what would be expected on a norm-referenced test (a nearly normal distribution with a mean of about 60 percent).

While a fairly elaborate set of criteria have been established for hours of remediation required by students receiving particular scores, no documentation exists to support this scheme. A particular fault is that the established 80 percent criterion used to judge that no remediation is required is far in excess of the level of performance which can be expected of most students on a test for which they have not directly prepared, and which covers such a broad range of topics. By this standard, almost all students might be expected to require at least some remediation. An equally important problem is that the instrument is not sufficiently reliable at the subscale level (by virtue of having only five items per subscale) to give a useful indication of student weakness in specific areas. The test is therefore not adequate for the purpose for which it has been designed.

The other side of the argument is that some parts of this test cover such basic topics as adding fractions and decimals, percentages, ratios, and solving single variable equations. The basic position taken in this report is that almost all students should have a high level of facility with such operations and concepts. One would certainly not expect post-secondary institutions to have to reteach such things. In this sense, results on the diagnostic test reinforce our argument that performance expectations of high school students are too low. The basic point is that the test is more useful for this purpose than as a diagnostic instrument.

Certain problems exist in the administration of such a test and in its possible use for placement purposes. In particular, students can be expected to write the test only if required. Unless written during the school year, major efforts are required to assemble students for the test. There are strong arguments against using the high schools as the vehicle for administering a test which is of value only to the post-secondary institutions. In any case, if the test is to be used as a basis for assignment to regular versus remedial courses, students could be expected over time to find ways to prepare for the test. In the extreme, one could envisage a summer tutoring industry to emerge or pressures to be mounted for schools to offer such services.

On balance, the Task Force is not convinced that the test adds sufficiently to our knowledge of specific weaknesses to be very useful as a diagnostic tool. Much more specific probing is necessary, and should be conducted as part of any diagnostic program. The test is much more useful as an indicator of general achievement levels. In particular, this kind of test would be quite helpful in tracking changes in overall capabilities of students, if used over a period of years. In the longer term, if some of the other recommendations in this report are followed, such a test would become redundant. Sufficient information would be available from the public examinations to identify areas of weakness. More important, such weaknesses should be overcome by taking a more rigorous approach in high school mathematics. The following is therefore recommended:

Recommendation 11.18

That the Fanshawe diagnostic inventory or similar test in mathematics not be implemented on a permanent basis for students entering post-secondary institutions.

Recommendation 11.19

That for the next three to five years, the diagnostic test remain in place as a supplementary indicator for placement purposes, and as a tool for longitudinal tracking of student achievement.

Recommendation 11.20

That any such test be administered during the first week or two of classes in the post-secondary institutions, rather than in the high schools or during the registration period.

Recommendation 11.21

That a suitable test be chosen for administration to mature students or others for whom no recent measure of mathematics performance is available. Placement of such students in remedial or regular post-secondary courses in mathematics should be based on performance on such a test.

CHAPTER 12

TEACHING CONDITIONS, PRACTICES, AND FACILITIES

In discussions on improving the quality of education, there is often a tendency to overlook completely the day to day conditions under which teachers and students function. In the final analysis, however, student backgrounds, curriculum, time, materials, and teacher training all come together behind the classroom door. It is here that the ideas and ideals underlying what the public wants and expects from education are put into practice.

Unfortunately, a short term policy study such as this is not the appropriate place to conduct an in-depth study of what happens in classrooms. Basic research on classroom functioning requires intensive observational work, which takes far more time than is usually available for policy studies. Fortunately, the past twenty years or so have seen a substantial amount of basic research on classroom life. Such research has shown clearly that teachers can make a difference to student achievement, and that not all teaching practices are of equal value. It is possible to draw from such research certain general prescriptions for the kinds of teaching practices associated with higher achievement. However, rather then pursuing these at length here, the matter of specific teaching techniques is left for preservice and inservice teacher education programs. The discussion in this chapter is confined to some general observations about structural features of classroom settings, and specific conditions of mathematics and science teaching which require amelioration. Few specific recommendations can be made, because circumstances in schools are so highly variable. Nevertheless, it is hoped that the points made will place in perspective some of the issues which concern many of those making submissions to the Task Force.

General Working Conditions of Teachers

Although the public image of teachers may be one of individuals who enjoy reasonably comfortable working conditions, high pay, and plenty of free time, the realities of day to day school and classroom work point to a rather different picture. By the standards to which most professional workers are accustomed, it no exaggeration to say that the conditions under which most primary/elementary and secondary school teachers work are exceedingly poor. For most of their working day, teachers are captives of the classroom location and of the school schedule. Compared to most professionals or to senior or middle management in business or public service, teachers have extremely limited access to support services such as clerical assistance, office space, copying machines, computers, and similar paraphernalia, or to budgets for the purchase of supplies and equipment. Even at their best, school staff rooms are a far cry from the comfortable offices enjoyed by other workers at similar levels. Finally, teachers work in a bureaucratic environment which severely limits the degree of professional judgement which can be exercised by the individual.

Teachers' salaries and benefits, though high by the standards of most workers, are modest by professional standards. Teaching also has a relatively flat career structure, with few opportunities for advancement. The only area in which teachers might be said to enjoy exceptional benefits is in the number of working days per year. For large numbers of teachers, however, much of this free time is occupied by efforts to achieve salary/certification gains, as this is essentially the only means of career advancement available.

It is instructive to compare the working conditions of public school teachers with those of their closest colleagues, teachers in post-secondary-institutions. While the salaries and benefits of the latter group are not notably better, post-secondary teachers generally have access to a far greater array of support services. University and college teachers take for granted the availability of secretaries, laboratory assistants, technicians, and a variety of other support staff. Private offices are also the norm in such institutions. On top of this, teaching loads are generally lower at the post-secondary level, especially in universities, where professors typically spend less than half the time in class as their public school counterparts. Although an argument can be made that university faculty are subject to pressures to attract funds, publish, and participate in administrative work, such work is generally under much greater control of the individual than is true for any aspect of the work of public school teachers. Overall, there is no doubt that the circumstances under which post-secondary teachers function are far superior to those faced by elementary and secondary teachers.

The opposite side of the argument about teacher working conditions is that teachers have managed, over the years, to negotiate a comprehensive array of job security arrangements which substantially restrict the flexibility of school boards to deploy teachers to best advantage. A certification/salary scale has also been entrenched in which salary is essentially unrelated to teacher competence, market conditions, or match between training and teaching assignment. Related to this is unrestricted access to the increased salaries associated with attaining higher certification levels, without reference to whether the area of upgrading improves an individual's ability to do a specific job. In the extreme, an argument can be made that teachers can enjoy substantial salary increases with no increase in capability to do the job assigned.

This is not the place for a full analysis of teacher working conditions, and certainly not for a critique of the teachers' collective agreement. However, several important points can be made from even this cursory account. First, any attempt to improve teaching by placing further pressure on teachers is unlikely to succeed. It is also important to point out, in the case of mathematics and science teaching in particular, that the kind of individuals we would most want to attract to teaching are likely to find many other alternatives available to them. The question of whether market conditions should be considered in attempts to recruit teachers in specific areas of specialization is therefore an important one. A related point, which is addressed more fully in later sections, concerns the effect of the certification/salary scale on the ability to upgrade teachers in areas of strategic concern. Finally, the point should be made that it is highly inefficient to use professional staff to do routine work, and even more inefficient to pay professional staff high salaries without giving them the tools necessary to do their job properly. The marginal cost of providing some of these tools is insignificant in comparison to the salary costs already being borne.

Class Size

The issue of class size is a perennial one in teaching. Teachers obviously have a strong interest in keeping class size small, for a variety of reasons. On the other hand, reducing class size is one of the most costly propositions governments can face, since cost increases in roughly direct proportion to any decrease in class size.

Recent syntheses of research on class size give a reasonably clear picture of the effect of class size on achievement.[1] Smaller class size is, indeed, associated with higher achievement. The problem is that the effects are relatively small for changes within the normal range. Reduction in class size from 20 to 10, for example, is likely to have much greater effects than reduction from 40 to 20. Either way, the cost is about doubled. Unfortunately, the first is generally not within reach without a major shift in our thinking about how schools are organized. In the latter case, if achievement gains were the only consideration, it is highly doubtful whether such a move would be cost-efficient.

In reality, the class size picture is much more complex than this. Class management is a serious concern, especially in settings such as laboratories, where close supervision and extra space are required. It might also be argued that small classes can be used to strategic advantage in special circumstances such as remediation or in dealing with special needs children. Smaller classes lend themselves to greater geniality and courtesy in interpersonal relationships. In many cases, sheer crowdedness is the issue. It is not uncommon to see classrooms where there is no room for either the teacher or the students to move about efficiently. Finally, smaller classes open the possibility of bringing about desirable changes in teaching style. The evidence, however, is that this does not always occur.

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[1] Glass, G.V., & Smith, M.L.. **Meta-Analysis of Research on the Relationship of Class Size and Achievement.** Educational Evaluation and Policy Analysis, 1, 2 - 16, 1979.

The overall student/teacher ratio in this province is such as to allow for average class sizes of about 20, even after allowing for non-teaching positions such as principals and guidance counsellors, and for those assigned specifically to special education. In practice, it has proven to be exceedingly difficult to obtain a true picture of actual class size. As near as can be estimated from surveys the average is about 25. What is most striking, however, is not the average but the extreme variability which exists. It is not uncommon to find classes in regular subjects (excluding special education) as small as 10 or 12 or as large as 35 or 40. Large classes tend to be found in large schools and small classes in small schools. Very small classes are often associated with attempts by small high schools to offer some course choice to students. For example, it is not unusual for a school with 20 or so students in a grade to split this group several ways to allow for course choice.

All in all, there is essentially no connection between actual class sizes and any particular goal of education or the demands of any particular subject. Class size is also largely unrelated to the overall student/teacher ratio. This ratio is the same throughout the province (except for some special arrangements for small schools), yet class size varies widely. Class size is determined largely by the exigencies of a school setting, and by choices made within a school or district. It is by no means clear that schools have allocated teachers in such a way as to minimize or equalize class size. In fact, in many large schools it is clear that class sizes have deliberately been kept large in the interest of using teachers for a variety of specialized purposes.

Ideally, one would like to argue for a strategic approach to class size, just as has been done for time allocations, so that class size could be matched to the requirements of particular kinds of activities. Unfortunately, schools are not constructed to allow for substantial variations in class size. In particular, few schools have space to accommodate larger groups for some purposes in order to achieve smaller groups for others. In the case of science and mathematics classes, the main argument in favour of smaller classes is the need for laboratory and problem-solving sessions. If larger groups cannot be established for lectures, for example, there remains a need for smaller groups in many cases for laboratory and problem-solving work. Within the limits of existing school architecture, the most obvious way of dealing with this problem is through the use of split classes. Although this is done in some schools in the province, it is by no means common practice.

Some will argue that such arrangements are impossible in most school settings. What the Task Force has seen over the past few months, however, has led to the view that some principals and teachers will treat as a routine scheduling matter what others will see as impossible. In some schools, pressure from the science teachers, or cooperation from principals, has led to arrangements which would be rejected out of hand in other schools. Split classes for laboratory work are clearly feasible in schools which have laboratory space dedicated to science. Such an arrangement is desirable in all cases where class size exceeds 20 or so. Until this occurs, there are definite limitations on what can be done. Nevertheless, it is obvious that the timetable should be subservient to the requirements of a course rather then the other way around, and that many schools have not explored the limits of what can be built into a timetable.

On the broader question of desirable class size, no clear statement can be made. There is no optimum class size, except perhaps one student to one teacher. The issue is entirely one of what cost the public will bear to have small classes, and of the particular teacher allocation policies used. Nevertheless, a couple of principles can be stated. First, classes should be as small as possible, within the overall teacher allocations available. Second, the number of non-teaching or specialized positions (teachers not assigned to a specific class) should be minimized, in keeping with the argument that the core subjects should receive priority. Third, and most important, every effort should be exerted to reduce the incidence of very large classes. When classes exceed 30 or so students, it is usually because the school has chosen to use some of its teachers for purposes other than regular classroom assignments. In high schools, this is often done in order to broaden the variety of course offerings. If the basic argument about a common program is accepted, the number of such courses should diminish.

Post-Secondary Class Sizes

It is difficult to generalize the research on class size to the post-secondary level because most of the research has been conducted in elementary and secondary schools. Common sense would suggest that as long as the principal class activity is teacher lecturing, then class size should not matter. The quality of the lecture, not the class size is the main issue. To the extent that having large classes forces a teacher to lecture when other techniques might be more appropriate, then class size may become a problem.

First year class sizes in mathematics and science at Memorial University have increased substantially in recent years. In some areas, the average class size has just about doubled, from 30 or so to near 60. At the other post-secondary institutions class sizes are deliberately kept small (usually 30 or fewer) through the use of admissions quotas and program-specific courses. Beyond the first year, there is a substantial drop in class size due to attrition and, in the university, to the much broader range of courses available to students. The change is so drastic that, at the senior undergraduate levels at the university, courses are substantially under-subscribed. This is also true to some extent for the other institutions, as attrition brings the numbers well below the numbers entering the program.

It is important to point out that, despite the substantial increase in class sizes at Memorial University, first year classes are still substantially smaller than those found in many other comparable universities in Canada. This is especially true in science courses, where class sizes of the order of 200 are not uncommon elsewhere. Only the smallest universities have class sizes comparable to those at Memorial. It appears that universities respond to enrolment pressures by increasing class size rather than increasing staff or teaching loads of staff. One might go further and argue that universities are able to maintain teaching loads much smaller than those in other educational institutions by creating class sizes that are well out of line with those found in other educational settings.

In science and mathematics, one of the main problems seems to be that most of the students taking first year courses are doing so to meet prerequisites for entry to professional faculties, and not to specialize in the science areas. Much of the teaching in these areas is therefore done as a service to other areas. Staffing policies in these departments, in the other hand, place much more emphasis on research capabilities than on first year teaching. Small first year classes would require that almost all teaching time be occupied with courses which are far removed from what is seen as the main function of faculty members. One might speculate, for example, that even if sufficient funds were made available to substantially increase staff in the science departments, these departments would have a strong interest in keeping first year classes large in order to find additional time for research. Certainly, there is little evidence of a commitment to small first year classes on the part of science departments.

Other post-secondary institutions have organized their first year courses along program lines. That is, a group of students admitted to a particular program, such as electronics technology, X-ray technology, or business administration, is treated as a unit for the basic mathematics and science courses. Class size is therefore determined by the quotas established for the various programs. In many ways, the problem of the Cabot, Fisher, and Marine Institutes is the opposite to that at Memorial University. Enrolments in basic courses are determined by the requirements of the overall program. These, in turn are related to job market demands, facilities for the technical courses, and other considerations having little do with the basic courses. This, together with high attrition at these institutions, leads to unjustifiably small class sizes in some programs. The contrast with the university is striking, especially when one considers that the non-university institutions also have much more time to cover comparable material.

This discussion provides further reinforcement for the basic position taken Chapter 7 that the university, and indeed the institutes of applied arts and technology, are not the most appropriate places to deal with the problems of first year teaching. A consolidated approach is required to remove the imbalances which now exist in class size, staff assignments and other features of the system, as well as to give more coherence to course content.

In our estimation, class size, in itself, is not the main issue at this level. Differential class sizes are required for different purposes. The striking difference between university and high school teaching in mathematics and science is that the university makes no arrangement for practice or problem-solving exercises. This point has already been addressed in the discussion of time allocations. All that needs to be added here is that any additional time allocated needs to be accompanied by appropriate size classes, if it is to be of most effect. Accordingly, it is recommended:

Recommendation 12.1

That post-secondary class size decisions be based on the principle that different size groups are required for different purposes. In particular, large lecture groups in mathematics and science courses should be divided into smaller units for tutorial, laboratory, or problem-solving activities.

Teaching Assignments and Subject Specialization

One of the most striking features of teaching in the schools of this province is the requirement that almost all teachers undertake assignments that are not within their specific areas of specialization. This is graphically illustrated by the Task Force Survey of high school teachers **(Background Report # 9).** Of those teaching mathematics and science courses in secondary schools, most are teaching only one class in a specific subject area. Those teaching the equivalent of a full load in either science or mathematics represent only a small proportion of the total. These figures, when taken in conjunction with figures on teacher qualifications presented in the next chapter, indicate that mathematics and science capabilities are spread quite thinly, and that many teachers have no opportunity to concentrate on a specific subject.

The last point illustrates one of the major dilemmas associated with teaching in this province. Most of our schools are so small that there is no way that teachers can be assigned solely to their areas of specialization. It is not even possible in many cases for a school to have one teacher in each major area of the curriculum. We are thus faced with the situation of having a teaching force which, though highly qualified in general terms, is not well matched to the specific assignments likely to be found in most of our schools. Mathematics and science suffer more than other areas from this problem, because of the relative shortage of teachers who have chosen to specialize in these areas.

The prevailing view in the field seems to be that specialization is required in some areas but not in others. A recent advertisement for teachers from a school board will illustrate the point. It was explicitly stated that a bachelor's degree in physical education was required for a physical education position, whereas the qualifications for a physics teacher were that a science degree was desirable but not necessary. It is extremely difficult to understand how this distinction can be justified. The only argument that seems to make sense is that there has been a tradition of considering physical education as a subject taught by specialists, while the same has never been the case for science. This is obviously not a sufficient argument.

The conventional answer to the problem of the nature of teaching assignments in small schools has been to call for teacher education programs geared to the generalist rather than the specialist. Arguments have been presented that teachers should not follow the conventional route of a subject major but instead should aim for breadth of training. (More will be said in the next chapter on issues related specifically to teacher education.) For the present, there is an obvious need to make some specific statement about desirable ways of assigning teachers, independent of the current situation, as a target towards which we should aim.

It is extremely difficult to demonstrate empirically that improved achievement results from exposure to teachers with specialized knowledge within a subject. Nevertheless, the view that specialized knowledge is required for competent teaching in a subject is more than an article of faith. Teachers who have come through the school system, and even through the first years of university under the conditions which now prevail in science and mathematics are obviously in no position to meet the much broader challenges of these subjects in the future. Those who have deliberately avoided science courses in university, or who have barely passed introductory mathematics courses are unlikely to develop an affinity to these subjects as teachers. Some recent research points to the importance of what is referred to as "pedagogical subject matter knowledge" or knowledge specific to the teaching of a subject. The best example of this for our purposes would be knowledge of the goals of mathematics and science teaching and the means of achieving these goals.

Virtually all over the world, calls are being made for the upgrading of mathematics and science teachers. If we continue to attempt to meet the needs of mathematics and science teaching by relying in the levels of competence attained by teachers who do not have these areas as their primary interest, there is a serious risk of falling even further behind than is now the case. Furthermore, a vicious circle is created. Teachers who themselves are marginally competent in a subject are unlikely to be able to convey to students what it means to strive for high achievement in the subject. Some of these students then go on to be teachers themselves, thus perpetuating the cycle. There is no particular incentive for a person to acquire the necessary background in mathematics or science as long as one's teaching assignment does not depend on one's competence in the subject. Furthermore, no guidance is available to student teachers on choice of areas of concentration. Under current circumstances, this creates a serious imbalance in the number of prospective teachers who choose mathematics or science, compared to areas such as English or history, as areas of specialization.

Despite these arguments, it has to be acknowledged that there may be overriding considerations at the primary and elementary levels. Whatever the need for competence in a subject, this must be secondary to the need for young children to function in a nurturing environment. It is generally acknowledged that this is best achieved by limiting the exposure of primary and elementary students to as few different teachers as possible. Unfortunately, this does not minimize the need for competence in mathematics and science for teachers at this level. It simply implies that a different approach must be taken to acquiring this competence than is true for high school teachers. Obviously, means must be found to allow all primary and elementary teachers to acquire the necessary knowledge.

At the same time, there is a need to have at least some teachers at this level who possess leadership capability in mathematics and science. As the next chapter will show, such capability is now almost completely lacking. The training and experience of program coordinators has been almost exclusively at the secondary level. There is virtually nobody in the elementary schools who has had any serious exposure to science, and only a few with the equivalent of a major in mathematics. It seems to be a reasonable target to aim to have at least one teacher in each school whose job it is to keep abreast of developments in mathematics and science, who can act as a liaison with the district office, and who can offer assistance to other teachers in the school.

Recommendation 12.2

That mathematics and science be considered as specialized subjects at the intermediate and secondary school levels, for purposes of teacher education, initial employment, and teacher assignments.

Recommendation 12.3

That appropriate subject area clusters covering both mathematics and science be formulated within both teacher education programs and school programs, to ensure that teachers in small schools can be assigned within their area or specialization.

Recommendation 12.4

That mathematics and science in the primary and elementary grades continue to be treated as part of the assignments of regular classroom teachers.

Recommendation 12.5

That school districts take steps, as opportunities arise in the course of school staffing, to ensure that each primary/elementary school is assigned at least one teacher with leadership capabilities in mathematics and science.

Classroom Practices

It is difficult for even an experienced classroom observer to make a coherent statement about the moment to moment activities which may be seen in classrooms. At one level, one is struck by an enormous sameness. At a more subtle level, there are equally enormous variations. Superficially, what one sees in almost all classrooms is one teacher, somewhere between 10 and 40 students, the teacher doing most of the moving and talking, the students usually sitting at desks listening, writing, and occasionally having to respond directly to a teacher question or direction. Closer analysis reveals much variation in the quality of discourse, the smoothness of classroom functioning, the level of active involvement of students, the kinds of materials used, and so on. More distinct variations can be found across subjects and grades.

Some have described classroom activity as a daily grind, aimed mainly at getting through the day. Others have more optimistically sought and found more or less subtle variations which can make a demonstrable difference to student task involvement and student achievement. Teaching itself has been variously described as an art, a craft, and an applied science. The setting is part learning, part social interaction, part workplace with its attendant power and reward structures, and finally part orchestration and organization. No matter what is being examined by the observer, it is difficult to escape the tremendous complexity of the setting, the large number of different interactions which occur, the crowdedness of many classrooms, the distinctly different roles of students and teachers. Again, we could go on. The point is that the classroom is a unique setting, different in important ways from other superficially comparable settings such as meetings, conferences, offices, or workshops.

As long as the existing structure of schools and classrooms remains in place, only certain kinds of changes are possible in the way teachers and students operate. Nevertheless, research on teaching has shown that certain kinds of classroom activities are more productive than others. In particular, techniques which maximize time use and reduce off-task behaviour, those which reduce the incidence of discipline and management problems, and those which maximize the active involvement of all students are the most productive.[2] [3] [4] There is also evidence that promoting cooperative learning among students is a productive strategy. These may seem like common sense prescriptions until we realize that classrooms vary substantially in the the use of such techniques. Some of these prescriptions also run counter to some firmly held notions about openness in classrooms and working with individual students.

It is not possible here to give a detailed set of prescriptions for good teaching practice. The ideas generated by recent research require intelligent interpretation within the context of preservice and inservice teacher education programs. Nevertheless, a general recommendation can be made about the principles around which desirable teaching practices can be developed:

Recommendation 12.6

That preservice and inservice teacher education programs be designed to ensure that teachers are made aware of recent research findings about desirable classroom practices in the areas of classroom management, time use, teacher-student interaction, cooperative learning, and other effective teaching strategies.

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[2] Brophy, J.E., & Good, T.H. Teacher Behaviour and Student Achievement. In M. C. Wittrock, (Ed.), **Handbook of Research on Teaching: Third Edition.** New York: Macmillan, 1985, pp. 328-375.

[3] Doyle, W. Classroom Management. In M.C. Wittrock (Ed.), pp. 392 - 432.

[4] Rosenshine, B. & Stevens, R. Teaching Functions. In M.C. Wittrock, (Ed.), pp. 376 - 391.

Ability Grouping

It has been pointed out elsewhere in this report, the school system has tended to operate on the assumption that large numbers of students are incapable of handling regular academic work, particularly at the high school level, and that this demands that programs be differentiated in such a way that less able students are exposed to material better suited to their abilities and needs. This assumption underlies what has been called the crisis of low expectations in the schools. This report has challenged this assumption, on the grounds of societal demands for an ever more highly educated populace, and specifically on the need for a common core of mathematical and scientific literacy for all.

The most common response in the schools to differences in student abilities has been streaming or ability grouping. A slightly more sophisticated response is differentiated programming, as illustrated by the revised high school program. However, program distinctions such as those between advanced and academic mathematics or between general and specialized science courses may still be seen as only a slight variation on the concept of streaming. In fact, a more direct form of streaming is still practised in some schools, whereby students within the same course are grouped by ability in the subject. This practice is especially prevalent in mathematics in some of the larger intermediate schools in the province, where basic, academic and advanced streams have effectively been created within what is designed as a common mathematics course.

If there is one thing which is clear from the educational research literature it is that streaming has detrimental effects on the very students it is mainly intended to help.[5] Streaming of low ability students almost always leads to reduced expectations and reduced performance for these students. Streaming persists because there is an abiding belief that it is easier to devise teaching strategies for a homogeneous group than for a mixed-ability group, and more fundamentally because erroneous assumptions are made about student abilities.

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[5] Oakes, Jeanne. **Keeping Track: How Schools Structure Inequality**. New Haven, Conn.: Yale University Press, 1985.

In an earlier chapter, it was argued that differential programming, and by extension, streaming, be replaced by differential time allocations as a way of improving achievement for all rather than entrenching low expectations. Nevertheless, streaming in one guise or another remains so firmly entrenched in teaching practices that a specific recommendation is required on this point.

Recommendation 12.7

That the practice of streaming or ability grouping for students be discontinued at all levels in the school system, and for all students except those with clearly identified special needs or talents.

Science Laboratory Work

Some specific comments are needed on the place of laboratory work in science. In most science courses, the laboratory is the place where it becomes possible to move from the codified knowledge of the textbook to the real phenomena underlying this knowledge. It is universally accepted that the laboratory is essential to meeting the main objectives of science teaching, and that laboratory activities should be an integral part of any science course.

Despite this, it is clear that the laboratory plays only a peripheral part in much of the science teaching that we have seen in this province. Most teachers and coordinators will admit this, and these admissions have been borne out by our surveys and observations. For example, the average number of laboratory sessions reported in both student and teacher surveys was about 10 per year. Significant numbers of teachers do no laboratory work at all. Several reasons have been advanced for the minimal use of laboratories. Inadequate facilities, large class sizes, lack of equipment, and lack of time have all been widely cited. However, the most striking reason is one which has been advanced by many teachers of the Level III high school courses. Put simply, many teachers believe that there is no advantage in doing laboratory work because the material covered in the laboratory is not tested on the public examinations. There is reason to believe that this view also extends to other senior high school courses.

The issues of time and class size have already been addressed. Facilities and equipment will be discussed in the next section. Here the point about public examinations is examined more closely because we believe that this says a great deal about how teachers define their roles, their perceptions of the nature of science, and their interpretations of the structure of the curriculum.

Teachers are correct in their observation that the public examinations do not cover the laboratory aspect of science courses. While most public examinations have for some years included an "investigative skills" item, this item has become quite stereotyped, and is easily answered without students ever having entered a laboratory. The question is whether this is sufficient reason to deemphasize laboratory work. One could argue, for example, that teachers have control of 50 percent of a student's final mark, and that this could be used to give credit for laboratory work. Our teacher survey, however, reveals that few teachers give more than nominal credit for such work. In fact, was argued earlier, teachers give most of their credit for tests and examinations designed to imitate the public examinations.

The main problem here is that teachers define their jobs in terms of what is required to get their students to succeed the public examinations. Since laboratory work requires substantial extra effort on the part of teachers, it is not surprising that such work would be given low priority when there is little perceived payoff. Furthermore, most of the curriculum guides now being used do not ensure that laboratory work is treated as an integral part of the course. We believe that the solution to this is not simply to exhort teachers to do a better job with laboratory work, but rather to devise curriculum documents and evaluation procedures which will ensure that this happens. To this end, it is recommended:

Recommendation 12.8

That all science curriculum documents clearly indicate specific laboratory activities which are integral to the course.

Recommendation 12.9

That specific expectations for evaluation and grade credit for laboratory work be indicated for each science course, and that public examinations be designed to include items specifically intended to test laboratory knowledge and skill.

Facilities and Equipment

If laboratory work is to be expected in science, then it must also be expected that the necessary space and apparatus be available to carry out such work. When planning the study, it was decided not to attempt a full scale inventory of facilities and equipment, as it was felt that this would yield an unmanageable mass of detail, not to mention placing a substantial burden on schools to supply the necessary information. Instead, it was decided to rely on interviews and school visits, along with experience from earlier observational studies. While this decision has prevented any quantitative estimate of the state of facilities and equipment, the impressions gathered are sufficient to give a general picture and to make recommendations in this area.

The most general observation which can be made is that there are enormous variations in the adequacy of space, the inventories of equipment carried by schools, and the funds available for the purchase of apparatus and expendable materials. Available space in schools covered the entire range from none at all, to laboratories used for a variety of purposes, including use as regular classrooms in other subjects, to dedicated laboratories directly under the control of the science teachers and used exclusively for their intended purpose. There seems to be no particular connection between the state of science facilities and age of building, school size, district affluence or any other obvious variable. About the only thing that can be said is that the availability of space depends to a degree on whether enrolment in the school has been increasing or decreasing. Some schools are badly pressed for space, while others have space to spare because of enrolment declines.

Variations in the state of equipment were found to be just as dramatic. Some schools have a large equipment inventory, built up over many years, to the extent that much of what exists is obsolete. Others have essentially nothing, and would have no place to put anything even if there were an influx of equipment. Schools have only one thing in common in this regard: it is clear that the annual budget allocation available for equipment is in no case anywhere near adequate even to meet the demand for expendable supplies, let alone to improve and update equipment.

If any generalization can be made, it is perhaps that basic laboratory space is usually more adequate than equipment. Overall, in fact, the Task Force observers were surprised at the number of high schools with dedicated laboratories, equipped with proper work tables, running water, electrical outlets and even gas outlets. In giving this generally positive assessment of facilities, however, the impression should not be conveyed that nothing needs to be done. The point we wish to make is simply that there is a need to target any attempt at upgrading facilities to the schools most in need, and not to all schools. It should also be noted that dedicated science facilities are usually found only in high schools. Many primary/elementary schools have what is referred to as a "multi-purpose room", but there is little to indicate that science is a prominent activity in most of these. In most of our schools, the intermediate grades (7-9) are located in the high schools, which allows access to whatever facilities are in place.

A strong argument must be made that the only suitable arrangement for intermediate or high school science is dedicated laboratories, used for no other purposes. Even when a laboratory doubles as a science classroom, its use as a laboratory is seriously restricted. When it is also used for other subjects, the situation becomes intolerable. A laboratory must be a place where apparatus can be set up in advance, and left in place as necessary. There must be some time between uses to make changes in setups. Laboratories must include storage space, have proper benches, and have running water and sufficient electrical outlets (gas outlets are less essential). Aside from the requirement that the laboratory room be free from other activities, such rooms are not suitable as regular classrooms in any case.

Facilities for primary and elementary science do not have to be so elaborate. Nevertheless, a regular classroom, with individual student desks, is not a suitable place to conduct science activities. At a minimum tables large enough to set up material and accommodate several students are required. Storage space and running water are also essential. Most of these requirements can be met with a multi-purpose room, as long as this room is not also used as a classroom.

The basic equipment in most high schools now allows for groups of four or five, or sometimes more, students to work independently. Rarely, however, would one find sufficient furnishings or apparatus for groups of two, which we would consider as ideal. In many cases, equipment is poorly maintained, having been purchased with the introduction of a new program, for example, but not replenished since. A fair amount of unusable equipment can also be found. This is especially true in physics and chemistry, where program changes have rendered some equipment obsolete. On the other hand, the main tool for biology, the microscope, seems to be in better supply than expected, despite the high cost of this instrument. Again, however, it is rare to find a school with one microscope for every two students in a class. Schools have also expressed some concern about lack of funds to keep microscopes in proper working condition.

The largest single problem of equipment and supplies is the size of the annual budgets allocated to schools for instructional materials. Specific policies on the allocation of funds for this purpose vary among school districts. These range from central office purchasing, to global allocations to schools, to specific allocations for science. Whatever the policy, however, the dollar amounts rarely exceed one thousand dollars per year, and are often only a couple of hundred dollars. Some schools supplement their basic allocations by fund raising or by charging laboratory fees. Occasionally, such as on the introduction of a new program or when teachers can make an exceptional case, schools may receive a short term infusion of funds.

Overall, however, the Task Force observers were struck by the impoverished state of most schools, and by the imbalance between expenditures on salaries, transportation, administration, and other items and those on the materials which can make an important difference between mediocrity and quality in instruction. One gets a strong sense that there is false economy in a system which considers the cost of instructional materials as a residual item, to be allocated funds only after all other costs are considered. In the extreme, it seems especially short-sighted to spend $ 40,000 to $ 50,000 to pay a science teacher, and then not give that teacher an additional $ 1000 or so to do a proper job. One gets a sense that for only a very small marginal cost, the effectiveness of science teaching could be improved substantially.

A specific note is necessary on supplies of chemicals. Many schools appear to have purchased a stock set of chemicals when the laboratories were initially set up or when chemistry was first introduced. Many chemicals in such sets are not necessary for the current course, or are not used for other reasons, such as safety, the lack of a fume hood, or the general lack of use of laboratories. Some substances deteriorate over time. Others require specific precautions for their storage. Many substances present major disposal problems. Overall, the problem of chemical storage, use, and disposal is sufficiently serious that the Department of Education needs a specific policy on such matters, and a means of monitoring the treatment of chemicals. This should be done with all urgency, before the issue is brought to a head by some accident.

It is one thing to be concerned that all schools have adequate facilities and equipment. It is quite another to ensure that such facilities are properly used. In our school visits, there was as much evidence of available facilities which are not used as of lack of facilities. A number of cases were found of schools with fully equipped dedicated laboratories where there was little sign that these had been used at all in the current school year. In some cases, this was clearly associated with the courses offered and the teachers assigned to these courses. However, it was also disturbing to find teachers who would present the argument that there is no advantage in doing laboratory work since such work is not tested on the public examinations.

What makes this so disturbing is not that teachers would take this position, but that no effort is made to examine laboratory work. In fact, a strong case can be made that, with the time pressures which exist in the curriculum, and the tendency to judge teachers on the basis of their public examinations results, teachers may find it detrimental to have their students spend time in laboratories. Whatever characteristics of the system which encourage teachers to forsake laboratory work must of course be removed. It might be argued, of course that a paper and pencil test at the end of the year is not the best means of testing laboratory work. This is where a clearer statement of the purposes of shared evaluation is needed, as we have already argued. In addition, revisions of curriculum documents are required to ensure that more than lip service is paid to laboratory work, that time is allowed for such work, and that specific requirements are laid out. All of these points have been addressed earlier in the report.

These points lead to the following recommendations:

Recommendation 12.10

That all intermediate and senior high schools provide space to be used exclusively for science laboratory work. The minimum requirements for such space should be laboratory benches with running water and electrical outlets, along with storage and preparation space.

Recommendation 12.11

That primary and elementary schools provide a multi-purpose room or science room equipped with tables, running water, and storage and preparation space.

Recommendation 12.12

That the Department of Education publish for each science course a list of recommended laboratory equipment.

Recommendation 12.13

That each school prepare an inventory of all existing laboratory equipment, and that this list be verified by science coordinators.

Recommendation 12.14

That the province provide a one time grant to each school for the purpose of upgrading equipment to a level which would allow laboratory work to be done by groups of two students.

Recommendation 12.15

That annual operating grants to schools be sufficient to cover the cost of maintaining and updating laboratory equipment and purchasing expendable supplies. A minimum grant of $ 1000 is suggested, with additional incremental amounts depending on school size.

Recommendation 12.16

That the Department of Education adopt a policy of supplying resources to ensure that schools are able to purchase the necessary equipment and supplies accompanying any new program introduced in mathematics and science.

Recommendation 12.17

That the Department of Education develop a policy on the purchase, storage, use, and disposal of chemicals used in science laboratories.

Computers

The supply of computer equipment to schools presents a number of unique problems. Like other aspects of facilities, there is wide variation in the availability and quality of computer equipment found in schools. School boards have also varied widely in their attitude towards providing computers and in their ideas on their use. On the one hand, computers seem to represent an area of prestige for a school, as illustrated by the willingness of some schools to raise money especially for such equipment. (The only other area which seems to attract so much fund raising is athletics.) On the other, computers have been used as symbols of the impoverished state of many of our schools. As discussed earlier, there is much confusion over the value of computers and over their specific uses in education. We have already made some general statements about the use of computers in schools and about the curriculum implications of the rise of computer technology. Assuming that agreement can be reached on what we want to accomplish in using computers, there remains the problem of supply of the appropriate equipment.

One thing is clear: even the best equipped schools cannot be said to have anything like the amount of computer equipment necessary to do an adequate job with computer studies and applications, as outlined in the curriculum chapter. Whatever equipment does exist in most schools has long since become obsolete. This, of course, is where the major problem lies. Microcomputer technology has advanced at such a pace in recent years that it has become an extremely expensive proposition to keep up to date in such technology. New equipment would need to be purchased almost every year, if this were the aim. At the same time, it cannot be said that the earlier investment in computing equipment has been wasted. Large numbers of students have emerged from the school system with at least a minimal sense of computer functioning. Even more important, many teachers have taken it upon themselves to learn about computers, and to prepare themselves for teaching in this area. We should now move ahead with a new round of investment in computer equipment, in the hope that even greater payoff will occur.

There is some consolation in the fact that most of the medium-sized microcomputers now on the market are capable of running a large number of applications programs of the type discussed earlier. These machines are becoming less and less expensive as more advanced systems emerge in the marketplace. Systems which cost $ 5000 only a couple of years ago can now be purchased for under $ 2000. If, as we have argued from the beginning, computers represent the essence of the ongoing transition to an information society, schools have little choice but to incur the same expense as all other sectors of society, in preparing their students for this transition.

It is difficult to make a specific recommendation on computer hardware. Since operating systems are now becoming more and more standardized, and peripheral equipment more compatible with a variety of basic machines, this is less of a problem than it was a few years ago. Only a couple of observations may be made. First, there is no doubt that an emphasis on applications requires that any systems purchased be IBM-compatible, based on the DOS operating system. Second, as already observed, medium scale systems, specifically those with fixed disk drives, are sufficient to run most of the software likely to be used in schools. An ideal system for school use would perhaps be one based on a local area network, with a central machine holding all the common software on a fixed disk, and several machines with floppy disk drives for individual use. Printers and other peripheral equipment could also be shared under such a network. It is important, both for purposes of economy in purchasing and for curriculum development reasons, to have a firm decision on one system for use throughout the province. Accordingly, it is recommended:

Recommendation 12.18

That the standard computing configuration for school use be one which functions under the DOS operating system and is based on a local area network incorporating a central device with a fixed disk drive, along with devices having floppy disk drives for individual student use.

CHAPTER 13

TEACHER EDUCATION

Teacher education in this province has been the subject of a recent major review.[1] The review has called for major changes in the structure and content of teacher education programs. These include proposals that an education degree be considered to be a professional degree, that the entrance standards to the Faculty of Education be raised, that an internship become part of degree programs of the Faculty, and that a plan for teacher renewal be developed by the agencies concerned.

The Task Force supports the general thrust of the recommendations of the review committee. There is therefore little need to take a comprehensive approach in addressing the issue of teacher education. Nevertheless, there are certain issues of teacher education which are unique to science and mathematics, and which thus require attention. Some of these have implications for teacher certification and other aspects of provincial concern beyond the immediate confines of university-based teacher education activities. These are issues the review committee had no reason to address.

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[1] Presidential Committee on Teacher Education. **Focussing our Future.** St. John's: Memorial University of Newfoundland, 1988.

Basic Characteristics of the Teaching Force

Even a cursory examination of basic characteristics of the elementary/secondary teaching force reveals some important points. The basic qualifications of teachers are high. Virtually all teachers now hold at least one degree. About 90 percent have completed at least one year of university study beyond the first degree. Nearly half hold at least two degrees, while about 12 percent hold master's degrees. This is in sharp contrast to the situation a couple of decades ago. Whatever criticism may be made of the quality of teacher education, there is no doubt that the programs of the past twenty years or so have met a very large demand for the upgrading of nominal qualifications.

Despite a substantial long term decline in school enrolments, the total number of teachers in the province has remained almost constant for a decade, while the previous decade saw substantial growth in the number of teachers, also in the face of enrolment decline. Teachers now typically make a career-long commitment to the profession, resulting in a fairly small turnover rate in recent years. The combination of lack of growth and low turnover has led to a gradual aging of the overall teacher population. On average, teachers now have had more than fifteen years experience, with most being at the top of the salary scale for their particular level of certificate. Teachers have continued to upgrade, though at a slower pace than in earlier years. The overall picture is therefore that of a mid-career teaching force, with little room for career advancement under the current certification/salary scale.

Behind these surface features, however, lie a number of trends and characteristics which suggest that growth in overall strength and qualifications of teachers may have had little impact on certain specific areas of school programs, particularly science and mathematics. First, it is important to note that much of the growth can be accounted for by two areas, special education and introduction of the revised high school program. The number of teachers added each year in special education has been almost sufficient to offset potential declines due to enrolment loss. In addition, new demand for several hundred teachers has been created by the revised high school program, not only as a result of the

Qualification	Level	
	Primary/ Elementary	Secondary
Total Teachers	3683	3996
Science Degree (including math)	50	489
6 courses or more in Science	108	619
6 courses or more in Math	354	898

Table 13.1
Mathematics and Science Backgrounds of Teachers

additional year, but also because of the accompanying broadening of programs and increased participation rates.

Much more important for our purposes is the fact that the teaching force is seriously imbalanced in areas of specialization. As Table 13.1 shows, the number of primary/elementary teachers who have chosen science majors is essentially zero. Even under a more liberal criterion of six semester courses, there are almost no teachers with science concentrations, and relatively few with a concentration in mathematics. The picture at the secondary level is slightly better, although when measured against the total place of science and mathematics in the high school curriculum the number is still substantially short of the demand. This is especially true if one considers the 6 course cutoff used in the table to be inadequate for competent teaching at the high school level (a point which will be addressed in a later section).

Teacher Certification

The basic question, of course, is whether it matters that a teacher possess a specific qualification in a subject area, or is the general qualification which goes with the award of a teaching certificate sufficient? The position of the Task Force on this issue has already been stated. Essentially, this position is that mathematics and science teachers at the intermediate and senior secondary levels should be considered as specialists. This raises the perennial issue of whether teaching certificates should reflect teachers' special competencies.

The current system sees certification and specialization as two separate issues. A teacher is awarded a certificate, and hence a position on the salary scale, on the basis of university credits and degrees. The matching of teachers to jobs, on the other hand, is a matter of hiring practices. Since there is no particular incentive for teachers to specialize in any particular area, and since many jobs involve teaching in a variety of areas, it is not surprising that serious mismatches occur in areas of specialization. This is especially true as teachers attempt to earn certification credits through part time studies, because there is a strong incentive to take whatever is available rather than anything matched to a particular teaching assignment. Mathematics and science have not been among the most widely available courses for teachers, nor is it clear that teachers would take such courses under current conditions even if they were made more available.

It has always been an article of faith in education that having more highly qualified teachers should yield improvements in educational quality. The current certification/salary scale has obviously been built with this in mind. This scale derives from a time of severe teacher shortages, when classrooms were staffed with many individuals who had barely completed high school themselves. The careers of many current teachers have been filled with periodic full-time and part- time upgrading efforts. In the 1960s and 1970s most such efforts were directed towards attaining the level of a first degree. Since then, large numbers of teachers have continued to advance on the certification scale through additional undergraduate and graduate programs. The overall picture, therefore, is one of a career-long continuing education effort.

It is important to note that teaching is the only profession which ties its certification and salary scales directly to university credits. In most other fields, university training establishes only the basic entry requirement. Certification is typically awarded after some further work such as internship in medicine or articling in law, and after writing licensure examinations. In teaching, certification is virtually automatic once the basic university requirements are met for the various levels. Moreover, in this province, the certificate essentially entitles a teacher to practice at any level or in any subject area, restricted only by school board hiring practices. In practice, this is only a slight restriction, because once in a job, teachers may be assigned to whatever areas are required by the school schedule.

With the strong incentives available for upgrading, one would think that it would be possible for teachers to acquire competence in the wide range of subject areas which characterize most of their teaching assignments. Unfortunately, this has not been the case. Certification requirements have been structured to fit established patterns in university degree programs, and not to fit the requirements of any particular job. A science teacher receives exactly the same credit for completing a master's degree in educational administration as in science teaching. The same credit is given for taking English courses as science courses. In short, the scale is based on the assumption that any one of a variety of routes to upgrading are of equal value, and that teacher competence is essentially unrelated to specialization.

This is where the Task Force sees the fundamental problem in mathematics and science teaching. While there is room for debate over the relative importance of subject matter knowledge versus professional knowledge, or over the precise requirements which would qualify an individual as a teacher of physics or mathematics, it is obvious that an individual cannot function adequately in a high school classroom without substantial depth of understanding in the subject being taught. More important, if our vision of the objectives of mathematics and science teaching is to be realized, teachers' understanding of the subject will have to go well beyond the knowledge contained in conventional specialized courses at the university level. The particular degree of depth required, and the specific mix of courses which would be appropriate would differ for elementary and secondary teachers. What is clear is that the current minimum requirements for elementary teachers are insufficient. For high school teachers, the problem is quite different. While the normal conjoint degree pattern might be considered sufficient, there are not enough individuals taking this route to yield the required supply, and not enough specialized positions to which such persons could be assigned.

All things considered, it is difficult to see how the necessary improvements in the match between qualifications and teaching assignments can be made without a radical overhaul of the certification/salary scale and of our definition of appropriate qualifications to teach in these areas. There is little point in exhorting school boards to hire mathematics/science specialists when these are in short supply, and when boards cannot offer assignments to specialized positions. Similarly, neither current nor prospective teachers can be exhorted to take courses in these areas when there is no particular payoff in terms of hiring prospects, salaries or teaching assignments, and when few courses are available in any case. The following sections present alternatives to the current situation, which, if implemented, would provide a means to ensure that all those assigned to science and mathematics teaching have an opportunity to acquire the necessary competence.

General Observations on Teacher Education

In this province, teacher education falls under the jurisdiction of a single institution, Memorial University. While this may seem advantageous in a small province, in terms of the ability to concentrate resources and to develop comprehensive programs, there is also danger in such a setup of program entrenchment and narrowness of thinking. The Faculty of Education at Memorial University has recently come under substantial criticism, culminating in the full scale review already mentioned. Some structural changes are about to be implemented, in the hope that these will yield ultimate substantive changes in programs.

The Task Force supports the general direction taken in the Review Committee's Report, especially the calls for increased admission standards, internship components for all degree programs, a plan for teacher renewal, reorganization of administrative units, and for increased sensitivity to problems faced by small schools. At the same time, we believe that there is a risk that structural changes will be used as a substitute for substantive ones. Unfortunately, the report says little about program specifics, and particularly about science and mathematics programs. Without repeating any of the arguments of the Review Committee, or taking issue with any of the major points, several further issues need to be addressed.

First, it is clear that there is a major problem of crowdedness in the teacher education curriculum and that this has been detrimental to the development of high levels of competence in mathematics and science. For example, despite the recent lengthening of the primary/elementary program to five years, teachers in the new program receive no greater exposure to mathematics and science than those in the previous program. Proposed revisions to the secondary program are also likely to reduce, if anything, the levels of concentration for science and mathematics students. Unless priorities are established, one can see that there might soon be an argument for a further increase in the length of all programs.

Second, the long-standing problem of balance between the professional and academic components of teacher education programs, and particularly of jurisdiction over the academic component, is by no means resolved by the report. A particular manifestation of this problem in science is the desire of the Faculty of Science to continue to determine the course structure and content for science majors under the proposed revised secondary teacher education program. (This proposal is designed to replace the current conjoint degree program with a five-year B.Ed. degree fully under the control of the Faculty of Education.) There seems to be nothing in this proposal that could not be resolved through dialogue between the Faculty of Science and the Faculty of Education. Unfortunately, there is a striking absence of liaison between the two faculties on such matters.

A comment is needed on graduate programs. For some twenty years now, the Faculty of Education has offered Master's degree programs in most of its departments. In general, such programs have been designed for the preparation of specialists and administrators. The most heavily subscribed programs have been in Curriculum and Educational Administration.

Since the certification regulations require teachers to complete a Master's degree before receiving the highest certificate level, it is not surprising that there has been substantial pressure on Master's programs. At the same time, because the certificate and its associated salary are not contingent on the area in which the teacher actually works, there is no means of matching area of specialty to area of work. Just as all other certificate levels, the benefits are the same whatever the specific job. Graduate programs are thus not a very useful tool for strategic upgrading of teacher qualifications. No matter what the shortage of, say, science teachers, there is no way to alleviate this shortage by using the available incentives for taking graduate studies. For the most part, in fact, graduate programs are a ticket out of the classroom for many individuals. In terms of classroom teaching, the payoff from the investment in salaries associated with the Grade VII certificate is doubtful.

Primary/Elementary Teacher Education

The current teacher education program for primary and elementary teachers requires a concentration in some subject area taught in the schools. Although teachers at this level are not expected to be specialists, the idea of a concentration is presumably designed to ensure that teachers have at least some area of special interest. It follows that the most desirable situation for schools would be to have on staff individuals having a variety of subject interests. This would allow for some leadership in each major area. It is obvious that the current system, for reasons that are not completely clear, does not attract primary and elementary teachers towards concentrations in mathematics or science. It is therefore not surprising that leadership is lacking and that science, in particular, receives low priority. Mathematics fares somewhat better in priority, if not in leadership capabilities, because its place in the curriculum is firmly established.

There are two major difficulties with most programs for primary/elementary teachers. The first is that, given an open choice of areas of concentration, almost nobody has chosen to concentrate in mathematics or science. The second is that, in an attempt to make the program as broad as possible, no area, except possibly the language arts, receives adequate attention.

It is interesting to note that certain subjects seem exempt from the pattern of generalist teaching in primary and elementary schools. Music and physical education are the most obvious examples. Special education is another, notwithstanding the trend towards integration of special needs children into regular classes. Some might ask, therefore, why the Task Force has rejected the idea of specialization at these levels in mathematics and science. There is little doubt that a high quality teacher education program could be designed for such teachers, perhaps by combining the two areas into a single concentration. We suspect, however, that such a program would attract few, if any, applicants unless strong special incentives were put in place. The result might be a worse situation than now exists.

The alternative is to strengthen the science and mathematics component of the existing program. One might have expected that this would have occurred upon the introduction of the revised five year program for primary and elementary teachers. Unfortunately, this has not happened. So many other demands were placed on this program that the time was easily filled without adding to these areas. In fact, some weakening has occurred with the removal of a science education requirement for primary teachers. In mathematics, there has been some change in the specific content of the first year course for teachers, but no increase in the overall strength of the program.

Given our argument that science, in particular, needs to receive higher priority in the primary/elementary curriculum, and that both science and mathematics have been identified as problematic, there is obviously a strong case for further emphasis on these areas in the teacher education program. If other existing areas are equally important, then this requires that the length of the program be increased. However, we are not convinced that this is the case. The time has come to establish some priorities in the program. Science and mathematics must take their place along with language as the highest priority areas. There is sufficient room in the existing program if we are prepared to make the appropriate choices. Accordingly it is recommended:

Recommendation 13.1

That the preservice teacher education program for primary and elementary teachers include at least four courses in science and four in mathematics.

Recommendation 13.2

That the preservice teacher education program for primary and elementary teachers include at least one course in science education and one in mathematics education as requirements.

Recommendation 13.3

That the science education course for primary and elementary teachers be upgraded to a full laboratory course.

The other area of concern in primary/elementary teacher education is that of how to ensure that a reasonable number of individuals choose to go beyond the minimum requirements, to permit the development of a corps of teachers capable of exerting leadership in these areas. It is obviously not sufficient to continue to draw upon those trained in secondary education for this leadership. The leadership is required at the school level. This demands that primary and elementary teachers themselves take on the responsibility. It has already been argued that school districts should attempt to provide for the necessary leadership through school staffing policies. Unfortunately, this cannot work unless there is a reasonable supply of teachers with the necessary qualifications.

The history of teacher choice of areas of concentration does not give reason for optimism that open choice will lead to a reasonable number of teachers selecting mathematics or science. Even developing programs designed to provide the appropriate concentration is of no use if nobody enrols in this program. More positive action is thus required. There are only two possibilities for developing a viable mathematics/science concentration in preservice teacher education. The first is through quotas on the numbers choosing other areas, such as English or psychology, so as to force prospective teachers in other directions. The second is some form of direct incentives in the areas of need. On the assumption that a positive approach makes more sense than a negative one, the latter course of action is recommended. Specific proposals in this area are presented in the following section.

Secondary Teacher Education

The problems in the preparation of secondary mathematics and science teachers are somewhat different from those for primary/elementary teachers. Few would argue that the current conjoint B.Sc./B.Ed. program provides an inadequate background in the student's major field. The current slate of professional courses in science and mathematics also seems adequate, at least in terms of time allocations. Nevertheless, the problem of insufficient numbers also exists at this level, though not to quite the same degree as in the primary/elementary program. There is also a problem of the appropriate mix of courses for teachers, especially those who will find themselves assigned to teach in a variety of areas.

The main problem is simply that too few prospective teachers have chosen science and mathematics concentrations. Although the conjoint degree program has been in place for over twenty years, there remains an acute shortage of teachers with appropriate qualifications in science and mathematics. A secondary problem is that a normal B.Sc. degree alone does not necessarily qualify an individual to teach the broad range of courses offered, nor are regular courses, designed for the preparation of scientists, adequate to address the much broader range of concerns reflected in the goals of mathematics and science teaching.

The problem is compounded by the non-specialized nature of teaching assignments in small schools, as already pointed out.

Plans are now under way for a revision of the secondary teacher education program which will allow for increased breadth in choice of academic courses. The general thrust of the revisions seems to be in the right direction. However, the university has been notoriously slow in developing the program, and it is not at all clear when a final version will emerge. There is disagreement both within the Faculty of Education and between that Faculty and other parts of the university on the structure of the program. Many members of the Faculty of Science, for example, insist that practising scientists within specific disciplines are the appropriate ones to decide on programs for teachers. The Faculty of Education has been equally adamant that its programs should be within its own control, just as is true for programs in other professional faculties.

The Teacher Education Review Committee has addressed this problem in general terms. There seems to be little point in reiterating all the arguments for and against the proposed revised B.Ed. program for secondary teachers. In any case, the problem of developing appropriate science courses for teachers, and of deciding on the nature of a concentration suitable for the realities of many of the schools in this province will not be solved under either arrangement unless there is greater cooperation between the Faculty of Education and the Faculty of Science than has been evident in recent years.

Part of the solution to this problem lies in a proposal on continuing teacher education to be developed in the following section. More immediately, it is useful to consider a possible program which would be especially suited for teachers in small schools. The basic argument here is that even in the smallest schools, there are plausible subject clusters in both teacher education and teaching assignments which would help optimize the match between qualifications and job requirements.[illegible] The obvious cluster for our purposes is science and mathematics. It is argued that in all but the very smallest schools, there is sufficient workload to allow at least one teacher to be assigned full-time to science and mathematics. Indeed, this is what is done in many schools. The problem is that a similar combination does not really exist in the teacher education program. We would simply recommend that such a combination should be developed along the following lines:

Recommendation 13.4

That a specific program route be developed for general mathematics/science teachers at the intermediate/secondary level, consisting of at least eight courses in one subject, six in each of three other subjects, including mathematics, and professional courses in both science and mathematics. The subjects eligible for such a combination would be biology, chemistry, computer science, earth science, mathematics, and physics, along with appropriate interdisciplinary courses designed to address directly the goals of mathematics and science teaching as outlined in this report.

On the problem of how to attract sufficient numbers to the science/mathematics route, there seems to be no alternative but to offer incentives for students to choose this area. While this may appear unfair to some, in that it gives preferential treatment to a specific group of teachers, it must be kept in mind that attractive alternatives to teaching are available to students with science backgrounds, and that providing incentives represents no more that a normal market response to shortage of supply. The only question is what form of incentive is most likely to work, and at what cost. The following recommendations may be taken as general statements of the need for incentives. The specific scale and mix of incentives is a matter of the level of funding the province is prepared to allocate .

Recommendation 13.5

That grants of $ 2000 per year be awarded to students beyond their third year of primary/elementary or secondary teacher education who choose a concentration in science and mathematics, and who maintain at least second class standing in their programs.

Recommendation 13.6

That a condition of such grants be that recipients agree to teach for two years in designated schools in the province, as determined by the Department of Education and the School Districts, subject to repayment of the grant if this condition is not met.

Recommendation 13.7

That all new teachers employed with appropriate qualifications in mathematics and science be paid a salary supplement of $2000 per year for the first three years of their teaching careers.

Continuing Teacher Education

The above measures should help ensure that the problems of the past are not perpetuated into the next generation of science and mathematics teachers. However, these measures will do little to relieve the situation in the short term. In any case, conditions are likely to change so rapidly over the next generation that even our best efforts in the next few years are unlikely to produce teachers who can comfortably spend a career without further upgrading. The need for continuing teacher education is thus more likely to increase than to diminish in the next generation.

As it now exists, continuing teacher education should be viewed as having two distinct components. the first is the upgrading for certification already mentioned. The second is what is commonly referred to as "inservice teacher education", and is associated with the allocation of a certain number of days in the regular school year for teachers to attend conferences, workshops, and similar professional sessions. The characteristic activity associated with this form of continuing education is the one day workshop for teachers in a school

Perhaps no aspect of teacher activity attracted as many complaints in submissions to the Task Force as the one day workshop. Complaints ranged from the inadequacy of such activities in familiarizing teachers with new curriculum materials, to the time wasted when schools are closed, to the cost of hiring substitute teachers to replace those attending workshops. The practice was so widely condemned that it seems just as well to recommend it simply be abandoned. Leaves of one or two days could, of course, continue to be used for purposes such as permitting teachers to attend conferences, briefing teachers on specific rules or regulations, or similar events.

Recommendation 13.8

That the practice of using one day workshops as a means of professional development for teachers be discontinued.

It has already been argued that most upgrading for certification purposes is irrelevant to job requirements. There is obviously a need for some entirely new approach to continuing teacher education. Two possibilities appear to exist. The first is to change the rules for certification to ensure that only those activities appropriate to teachers' job assignments are eligible for credit. The second is to institute a separate system of upgrading, independent of the certification requirements. Either way, it seems necessary to separate professional development related directly to the job from the more general system of university credits. In practice, what seems to be happening in certification is that teachers are moving fairly quickly to the Certificate VI level but much less quickly to Certificate VII for which the requirement is a Master's degree. Since more than half of all teachers now hold Certificate VI, there is little room to use certification as a vehicle for job related upgrading unless the requirements for Certificate VII are modified substantially.

Our basic proposal, then, is that an alternative to certification upgrading must be found. Here is it useful to look to normal practices in other areas of employment. In most business settings the practice is simply for the employer to offer any training needed to meet the requirements of a particular job. Such training is not necessarily tied to promotions or salary advancement, although these may occur as side effects. The purpose of the training is simply to make the employee perform better in ongoing or new assignments within the business. Excellent examples of this are found in the automotive and computer industries, as well as in most other areas where continual upgrading of technical skills is essential to the survival of the business. In education, large amounts of resources are spent on an upgrading system which is much too diffuse to be of great value in updating teacher capabilities to perform a specific job or to take on new assignments.

In teaching, it would be almost impossible to conduct the scale of upgrading needed during the school year, since every teacher released for such work would have to be replaced. The alternative is, of course to use summers for this purpose. Teachers are quite accustomed to using summer time for upgrading, so this would not represent a great departure from existing practice. The key requirement would be to provide incentives equivalent to those now available for the more general upgrading associated with certification.

While this could be done by simply changing the certification regulations, it is felt that a better alternative would be to pay teachers directly for participation in such activities. If this were done, there would likely be a noticeable decrease in pressure to upgrade certificates, at a cost saving which would help offset the added cost of the new program. The main advantage, however, would be that once such programs were available, teachers could be required to participate as a condition of being able to take on a particular assignment. The system could also emphasize certain strategic areas over a period of time, sufficient to ensure that all teachers working in the particular area of emphasis could receive the necessary upgrading.

It is suggested that these ideas be tried on an experimental basis over the next five years, specifically in mathematics and science. This would give an opportunity to test the viability of the scheme and assess its costs and benefits, while making some specific progress in an area in which some alternative to the existing system must be found. The following recommendations are designed to provide a rough outline of the shape of the proposed program.

Recommendation 13.9

That teachers be paid direct stipends to participate in summer programs in strategic areas where upgrading is required, as an alternative to receiving credit on the certification/salary scale.

Recommendation 13.10

That such summer programs be planned and administered jointly be the Department of Education, the Newfoundland Teachers' Association, Memorial University, and the School Districts, and be made available on a regional basis.

Recommendation 13.11

That immediate priority be given to summer programs in elementary and intermediate science and in intermediate and senior high school mathematics.

Recommendation 13.12

That such programs be offered on a sufficient scale to allow all teachers with more than 10 years experience who are teaching in the appropriate areas to participate within the next 5 years.

Recommendation 13.13

That participation in such programs be made a condition of continuing to teach in mathematics and science after the five year initial period has ended.

Recommendation 13.14

That summer programs be staffed by members of the Faculty of Science and the Faculty of Education at Memorial University, science/mathematics coordinators and others with appropriate qualifications.

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APPENDIX A

LIST OF BACKGROUND REPORTS

APPENDIX A

LIST OF BACKGROUND REPORTS

	Author	Title
1.	Robert Crocker	Achievement in Mathematics and Science
2.	Robert Crocker	Science Achievement in Canada: Interprovincial Comparisons
3.	Helen Banfield	Enrolment and Participation in Mathematics and Science
4.	Helen Banfield Warren Cole Lloyd Gill Jacinta Sheppard	Mathematics and Science Curricula in Canada: Comparative Analyses
5.	Gary Hancock Janice Kelland Bernard Rice Cyril Snook Donald Rideout J.R. Pickavance	First Year Mathematics and Science Programmes in Selected Canadian Universities: Comparative Analyses
6.	Leslie McLean Warren Cole Lloyd Gill André Grace Frank Murphy Cheryl Perkins	Public Examinations: Comparative Analyses and Critique

7. Cheryl Perkins	High School Mathematics and Science: A Survey of Grade 12 Students
8. Dolores Mills	Secondary and Post-Secondary Mathematics and Science: Initial and Follow-Up Surveys of First Year Students
9. Marian Fushell	High School Mathematics and Science: A Survey of Teachers
10. Helen Banfield	Mathematics and Science in the Early Grades: A Survey of Primary and Elementary Teachers
11. Helen Banfield	First Year Post-Secondary Mathematics and Science: A Survey of Instructors
12. Helen Banfield	Summary of Focus Group Discussions: Memorial University Students
13. Helen Banfield	Summary of Interviews with School District Personnel
14. Charlotte Strong	Summary of Submissions to the Task Force
15. Charlotte Strong	Public Opinion on Education: A Newfoundland Survey

APPENDIX B

LIST OF SUBMISSIONS

LIST OF SUBMISSIONS

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Mt. Pearl

Mrs. Day-Careen
St. John's

Abraham and Susan Ross
Paradise

Dr. and Mrs. A. King-Harris
St. John's

Eloise Lemire
St. John's

Mrs. Bridget Lake
St. Lawrence

Mrs. Donna Reid
Bishops' Falls

Mrs. A. W. Wall
Mount Pearl

William Holt
Buchans

Gerard Sampson
Churchill Falls

Selena Delahunty
St. John's

Velma Brown
Salvage

Ruth Brown
Glenwood

Melanie Keough
Parson's Pond

Pansy Rice
Baie Verte

Anna Martin
St. John's

P. C. Helwig
St. John's

David A. Snow
Mt. Pearl

Marilyn Dumaresque
L'Anse au Clair

Eric Roger
Gambo

Bert Lane
Dunville

Raymond Rose
Labrador West Integrated School board

Edward Downey
Beothuk Collegiate
Baie Verte

Don Downer
Science Co-ordinator
Bay of Islands Integrated School Board

Sister Loretta Chafe
St. Bride's Convent
Littledale

Mrs. Elizabeth Murphy
Christ the King School
Rushoon, P. B.

Albert and Trudi Johnson
Menihek High School
Labrador City

Dr. C. K. Brown
Former Director of Instruction
Department of Education
St. John's

Mathematics and Science Teachers
Ferryland Roman Catholic School Board
via Damien Collier, Mathematics / Science Coordinator

Marine Institute

Cabot Institute

Pritam S. Cheema
Cabot Institute

Dennis Acreman
Marine Institute

Ian Mennie
Grenfell College

D. H. Rendell
Department of Physics
Memorial University

Geoff Rayner-Canham
University of California and Grenfell College

Debbie Rehner
Marine Institute

Bruce Shawyer
Mathematics Department
Memorial University

Michael Collins
Director of Division of General Studies
Memorial University

B. G. Sanderson
Physics Department
Memorial University

Peter Booth
Mathematics Department
Memorial University

Curriculum Committee
Physics Department
Memorial University

Hugh Miller
Chairman,Undergraduate Committee
Department of Earth Sciences
Memorial University

Alan Griffiths
Department of Curriculum and Instruction
Faculty of Education
Memorial University

Georg Gunther
Coordinator of Mathematics
Grenfell College

J. N. Bridson
Chemistry Department
Memorial University

Jeanette Walsh and June Jones
General Hospital School of Nursing

Arthur Leung
Department of Career Development and
Advanced Studies

Harvey Weir
Department of Physics
Memorial University

Edward Sheppard
Principal
Ralph Laite Pentecostal Collegiate

John Bartlett
Science Department
Booth Memorial High School

Roncalli Central High
Avondale

Robert H. Rose
Mathematics Department
Prince of Wales Collegiate
St John's

Sam Chaulk, Principal
St. James Regional High School
Port aux Basques

Ross Rumbolt
Program Co-ordinator
Vinland Integrated School Board

Robert Simms and Bruce Vey
Labrador East Integrated School Board

David Quick
Math/Science Co-ordinator
Roman Catholic School Board
Conception Bay North

Avalon North Integrated School Board

Allan MacNeil
Assistant Superintendent
Bay St. George Roman Catholic School Board

Bob Wells, Mathematics Coordinator
Tom Leonard, Science Coordinator
Avalon Consolidated School Board

William C. Lee
District Superintendent
Conception Bay South Integrated School Board

Roger Taylor
Program Coordinator
Labrador West Integrated School Board
Roman Catholic School Board for Labrador

Burin Peninsula Integrated School District

Green Bay Integrated School District

Roman Catholic School Board
Exploits-White Bay

Graham Blundon
District Superintendent
Deer Lake Integrated School Board

Joe Murcell
Mathematics Science Coordinator
Port aux Basques Integrated School Board

Frank Murphy
Science and Mathematics Coordinator
Placentia-St. Mary's Roman Catholic Board

Bonavista-Trinity-Conception Integrated School Board
Clarenville

Roman Catholic School Board for St. John's

Pentecostal Assemblies Board of Education
Windsor, Newfoundland

Roman Catholic School Board
Burin Peninsula

Exploits Valley Integrated School Board
Grand Falls

Denominational Education Councils

The Newfoundland Teachers' Association

Montford Pritchett
Avalon Regional Math Council
Newfoundland Teachers' Association

Herbert Penney-Flynn
Elementary Teachers' Special Interest Council
Newfoundland Teachers' Association

Newfoundland Teachers' Association
Humber Branch
Corner Brook

Newfoundland Teachers' Association
Mathematics Council
Kay Whelan, President

Government of Newfoundland and Labrador
Department of Education
Science Consultant, Harry Elliot

Government of Newfoundland and Labrador
Department of Education
Mathematics Consultant, Wilbert Boone

Cyril Pinsent
Newfoundland and Labrador Association of
Superintendents of Education

Dorothy Robbins
Women's Policy Office
Government of Newfoundland and Labrador

Martha Musychka
Ad Hoc Committee on Young Women's Issues

Ann Bell
Provincial Advisory Council on the Status of Women
Newfoundland and Labrador

Newfoundland and Labrador Association for Gifted Children
Ralph Morris, President

Audrey Hodder
Convenor for Education
Gander Branch
Newfoundland and Labrador Women's Institutes

Ferne Foley
Hillview, T. B.

Philip Thornley
Campbellton Berry Farm

Stanley Sparkes
Glovertown

James Barter

Nine telephone calls

Two anonymous letters